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PRACTICAL HANDBOOK

OF

MEDICAL ELECTRICITY

FOR

STUDENTS AND PRACTITIONERS

By HERBERT MCINTOSH, A.M., M.D.

MEMBER OF THE AMERICAN MEDICAL ASSOCIATION, FELLOW OF THE MASSACHUSETTS MEDICAL SOCIETY, FELLOW OF THE NEW ENGLAND ASSOCIATION FOR PHYSICAL THERAPEUTICS, MEMBER OF THE AMERICAN ELECTRO-THERAPEUTIC ASSOCIATION, ETC., ETC.

Containing over two hundred illustrations

THERAPEUTIC PUBLISHING COMPANY, INC.
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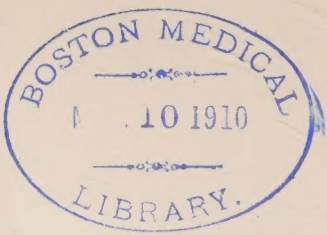

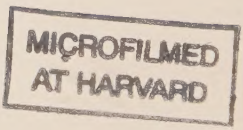

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chronic. Pharyngitis acute. Pharyngitis follicular. Pharyngomycosis. Prolapsus uteri. Prostatic hypertrophy. Pruritus. Psoriasis. Purpura. Raynaud's disease. Rhinitis acute, chronic, hypertrophic, hyperesthetic, atrophic. Retinitis. Salpingitis. Sarcoma. Scrofuloderma. Sciatica. Scleritis. Spasm of pharynx. Spermatorrhea. Stricture of canaliculus, esophagus, rectum, urethra. Subinvolution of the uterus. Syphilis of the skin. Tachycardia. Tattoo marks. Tinnitus aurium. Torticollis. Trachoma. Trichiasis. Tinea favosa, versicolor, capitis, barbae, corporis. Tonsillitis. Tonsil lingual, hypertrophy of. Tuberculosis pulmonary. Urine, incontinence of. Urticaria. Uvula, elongation of. Varicocele. Vomiting. Warts Wounds.

PREFACE

In the following pages an effort has been made to present a somewhat more adequate treatment of the physics and physiology of the natural forces whose aid, at the present time, is increasingly invoked in the treatment of disease, than is usually found in text-books upon physical therapy. There can be no genuine confidence in the utility of physical therapy which is not founded upon an accurate knowledge of the physical and physiological characteristics of the agencies which are employed. When these are carefully studied and analyzed their applicability to the treatment of disturbed bodily conditions begins to emerge. Therapeutics is no longer imitative or empirical, it becomes rational.

Beginning, therefore, with simple experiments, the author has endeavored to present as far as possible an inductive outline of the physics of the subjects treated, conducting the reader through the fields of direct, inductive, static, and high frequency electricity and the related and adjoining territories of the X-ray, light, and radium. Employing as far as possible the art of condensation, he has brought into single chapters a consideration of the physical and physiological effect of the different types of forces discussed, so that the reader may readily find

what he seeks without turning to different portions of the book in order to bring together the scattered parts of a fragmentary treatment. So far as possible the author has omitted merely theoretical or speculative discussions and sought to confine himself to facts and principles which have obtained universal consent.

In Part II he has limited himself to the therapeutics of the various disorders discussed, omitting, for the most part, etiology, pathology, symptomatology, and diagnosis. In some instances he has indicated which treatments are in his judgment best adapted to secure the results desired. In general, however, if the student has thoroughly mastered the principles explained in the previous chapters, he will have little difficulty in deciding, in any instance, which is the treatment of choice.

The reader will perhaps be impressed with the space and time given to the discussion of the direct current, and to the share which it enjoys in the treatment of disease. The same may be said of light. The continuous current has been somewhat neglected of recent years, owing, no doubt, to the introduction of newer and more spectacular forms of treatment. It is well to remember, however, that the current about which most is known, which possesses the invaluable characteristics of polarity and electrolysis and against which the charge of suggestive therapeutics has least weight, is the continuous current. In the judgment of the author its possibilities are but imperfectly understood, and its

great usefulness but slightly appreciated. The same remark is applicable to sunlight and its efficient substitute, the arc light.

In order to understand high frequency currents it is necessary thoroughly to be acquainted with induced currents.

The author has therefore striven to give sufficient space to the discussion of these currents to make high frequency apparatus and the method of production of high frequency currents intelligible to the reader. Nobody at this moment is able to assert with perfect confidence the exact role which high frequency currents are destined to play in electrotherapeutic practice. Much more study is needed to determine their true value. When the period of enthusiasm following their first introduction has somewhat subsided, we shall be better able, perhaps, to make a truer appraisal.

With regard to the X-ray the author feels that the profession is much more likely to underrate than overrate potentiality of this remarkable energy. The power which it has to do harm directs attention to the great capacity it has under competent management and control to do good. Its immense contribution to medicine upon its diagnostic side is everywhere conceded.

In the preparation of this work the author has freely consulted all authorities which were accessible, and hereby acknowledges his obligation to all workers who have preceded him in this field of therapeutic endeavor. Among these are Drs. Beard

and Rockwell, Dr. H. Lewis Jones, Dr. Dawson Turner, Dr. Jacoby, Dr. Wm. B. Snow, Dr. Monell, Dr. Kassabian, Dr. Cleaves, Oliver Lodge, and many others.

Among text-books on physics he has derived most assistance from Ganot's Physics. He has made free use of current electro-therapeutic publications, among which he may mention " The Archives of the Roentgen Ray " and " Archives d'Électricité Médicale." The thanks of the author are also due to those who have kindly lent their assistance by supplying electrotypes for illustration of the text.

The author trusts that the book herewith submitted to the public may contribute to greater precision in the use of these newer weapons supplied by physical science to the arsenal of the progressive physician.

419 Boylston St.,
Boston, Mass.

PART ONE

PHYSICS AND PHYSIOLOGY

OF

ELECTRICITY, THE ROENTGEN RAY, RADIUM, AND LIGHT;

TOGETHER WITH A DESCRIPTION OF THE

VARIOUS METHODS OF TREATMENT

EMPLOYED IN

PHYSICAL THERAPY

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CHAPTER I

ATOMS. ELECTRONS. ELECTRIC THEORY

The atomic theory as announced by John Dalton, in 1804, declares that the ultimate unit is the atom, and, as its name indicates, that it is indivisible. Researches into the nature of the kathode stream of the Crookes tube and the beta ray of radium render it practically certain that the atom is composed of a collection of smaller corpuscles, or centers of force, which have been called electrons. In the kathode stream these corpuscles are repelled by negative electricity. They are consequently negative. They constitute the electric current, whether detached from atoms in rarefied gases, associated with atoms in the electrolysis of fluids, or passed along from atom to atom in the conduction of solids.

In the kathode stream the so-called corpuscles are evidently not associated with what is commonly called matter. They are electrical charges so minute that they constitute about the one thousandth part of a hydrogen atom.

The association of these " charges " or corpuscles in groups varying in number, in possible arrangement and in speed of vibration or orbital motion, constitutes the atom. Whether there is anything else associated with these electrical charges in the atom

is an undetermined problem. The difficulty in solving this problem arises from the fact that the positive electron, if there be such a thing, has not been isolated. What positive electricity is, has, therefore, not been determined. Is it the combined effect of a collection of negative electrons revolving in a system around a central sun, from which occasionally under appropriate conditions a number of electrons are thrown off from time to time; is it a collection of positive and negative charges, in equilibrium under ordinary circumstances, but likely to be disturbed by external conditions; is it a charge associated with matter, so-called, sufficient to neutralize the negative charge belonging to the electron; is it simply the atom manifesting a new property through the defect of some of its electrons, or is it a collection of electrons floating in a sphere of positive electricity, whatever that may mean? Each of these suggestions has been made in the attempt to obtain a mental picture of the ultimate condition of the atom. It thus appears that, while the acquisition of a large mass of new facts in relation to electricity has rendered the older theories as to the nature of matter or its ultimate constitution untenable, it has not as yet been possible to present an intelligible or coherent statement upon this difficult question, or to substitute a new conception which is adequate to explain all difficulties. More study is needed, and more facts are required before a perfectly lucid hypothesis can be formulated. It is sufficient to say that there is a growing tendency toward the recognition of elec-

tricity as the source of the phenomena to which we apply the name matter. Meantime certain definitions and provisional statements may be made involving the newer conceptions of electricity.

An electron is the unit electric charge.

An ion is an atom with an unbalanced electric charge.

Chemical affinity is due to the attraction of atoms with unbalanced electric charges.

A hydrogen atom contains from seven hundred to one thousand negative electrons.

The physical properties of the elements are due primarily to differences in the number of electrons contained in the atom. Thus the atomic weight of hydrogen being one and that of mercury two hundred, we are to infer that the mercury atom contains two hundred times as many electrons as the hydrogen atom.

The ether is a hypothetical medium of perfect elasticity which fills all space.

Radiation is due to the acceleration or retardation of electric charges.

Radiation manifests itself by the production of waves in the ether. These range from the waves of greatest length, called Hertzian waves, to waves of shortest length produced by the impact of negative electrons upon the target of the X-ray tube, or the so-called Roentgen rays.

Throughout this work it will be noted that the terms direct current and induced current are substituted for galvanic current and faradic current, as

being in harmony with the usage of electrical engineers. There would seem to be no reason why physicians should continue to use terms long since abandoned by the scientific world.

CHAPTER II

PHYSICS OF THE DIRECT CURRENT

If a strip of zinc be immersed in a dilute solution of sulphuric acid, a chemical action at once ensues, in which the zinc is attacked by the sulphuric acid with evolution of heat and bubbles and which may be expressed by the following equation:

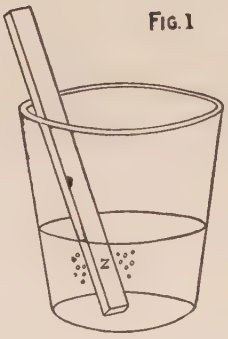


Fig. 1

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

In this reaction free hydrogen has been liberated, which manifests itself as bubbles rising to the surface, and a salt of zinc formed, namely zinc sulphate, which remains in solution. (*Fig.* 1.)

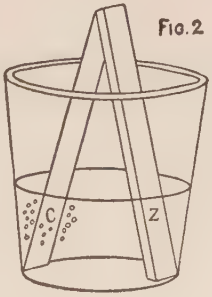


Fig. 2

If now another substance, as for example copper, be immersed in the same solution without touching the zinc, the evolution of gas ceases; but if the ends of the metals above the surface of the fluid are allowed to touch, a stream of bubbles will now rise from the copper and only a few

from the zinc. After a while the zinc will be found to have wasted away, while the copper has remained unchanged. (*Fig.* 2.)

If now a wire be attached to the ends of the plates above the solution and an ordinary compass placed under and parallel to them, and the ends of the wires brought together, the needle is immediately deflected at an angle. If the ends of the wires be separated, the needle returns to its normal position. (*Fig.* 3.)

The something which passes through the wires

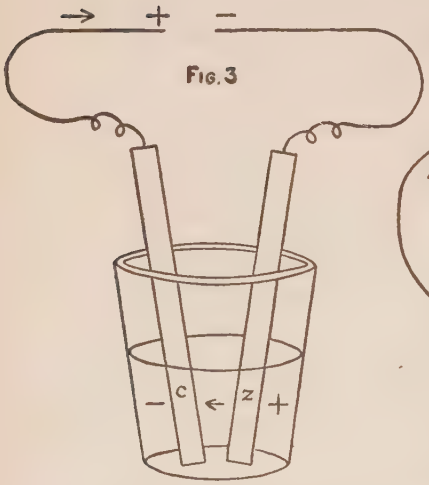
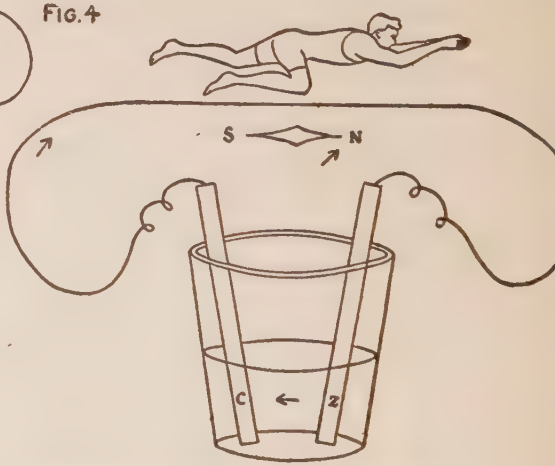


FIG. 3

FIG. 4



in these simple experiments, and which is a correlative or sequence of the chemical action upon the strips of zinc in the first experiment is by common consent called electricity, the direct current, or galvanism, and is the foundation of our studies in these chapters.

The metal which is most vigorously attacked is called positive, that which is least actively attacked negative. But the end of the wire attached to the zinc strip is negative, while that attached to the copper strip is positive, because that plate and that end of the wire are positive *from* which the current flows and that plate and that end of the wire are negative *to* which the current flows.

In the experiment above described we showed that something was flowing through the wire by the deflection of the needle. To enable us to determine the direction of the deflection we may employ Ampere's rule, which is to imagine ourselves swimming in the current and facing the needle, in which case the north end of the needle will always be deflected to the left. (*Fig.* 4.)

An instrument which enables us to detect the presence of an electric current is called a voltameter, and one which enables us to measure an electric current is called a galvanometer. Such an instrument is essentially a permanent magnet so arranged that it can be deflected from its natural position by the passage of a current of electricity through an adjacent coil or coils of wire. (*Fig.* 5.) If an index is connected with the

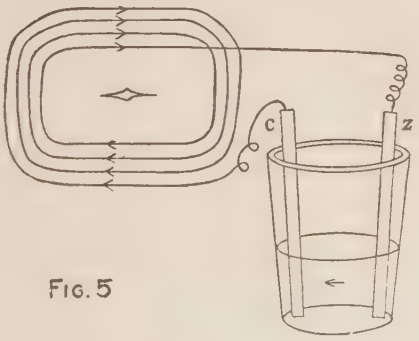


FIG. 5

magnetic needle and made to traverse a graduated scale, we have a means of determining, by reference to a unit previously agreed upon, the amount of the current which is passing through the coil. Such an instrument, if graduated in milliamperes, is called a milliamperemeter, or mil-ammeter.

By introducing coils of wire of different lengths, different diameters, and different materials in the circuit of a direct current battery certain very important principles may be deduced:

(1) The strength of current varies directly with the areas of the cross-sections of conductors.

(2) It varies inversely with the lengths of conductors.

(3) It varies inversely with the specific resistance of the substances used as conductors.

The power which sets electricity in motion, as in a voltaic cell, is called the electromotive force, which is abbreviated to E. M. F. or simply E. This varies in different cells, and is dependent upon the nature and character of the substances forming the battery and is independent of the size of the plates and their distance apart.

The unit of E. F. M. is called a volt, and is about equal to the current generated by one gravity cell or one Daniells cell.

To determine the strength of current or rate of flow through a conductor the formula known as Ohm's law is employed. This is: *The current strength is equal to the electromotive force divided by the resistance of the circuit.* This may be expressed

as an equation, thus: $C=\frac{E}{R}$, in which C stands for current strength, E for the electromotive force, and R for the resistance of the circuit. By transformation this becomes $R=\frac{E}{C}$ and $E=RC$.

The unit of resistance is the ohm, which is the resistance offered by about one hundred and fifty feet of copper wire one millimeter in diameter, or it is the resistance offered by a column of mercury one meter high and one millimeter in diameter.

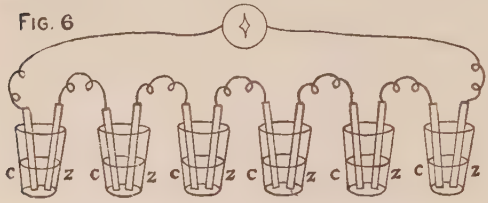
The unit of current strength or rate of flow in a unit of time is the ampere. This is furnished by the E. M. F. of one volt passing through one ohm of resistance. That is, using Ohm's law, $\frac{1}{1} = 1$ ampere; or it is measured by the amount of water the current will decompose into oxygen and hydrogen in one second at 0° C. temperature and 760 millimeters pressure.

The study of the effect of resistances upon the electric current is of extreme importance, and lays the foundation for an intelligent application of medical electricity. We may amplify the above equation $C = \frac{E}{R}$ by writing it thus, $C = \frac{E}{ir+er}$, where *i r* stands for the internal resistance, or the resistance of the current in the battery, and *er* for the external resistance, or the resistance in the external circuit. In order, therefore, to increase the current we must either increase the numerator or decrease the denominator; and to decrease the current we must either decrease the numerator or increase the denominator.

There are two principal methods of arranging

cells to form a direct current battery. The first arrangement connects the zinc plate of one cell with the copper plate of the adjacent cell and finally connects the negative of the first with the positive of the last. (*Fig.* 6.)

Fig. 6



The second arrangement connects all the positives of several cells with one another and similarly all the negatives, and finally connects the two sets

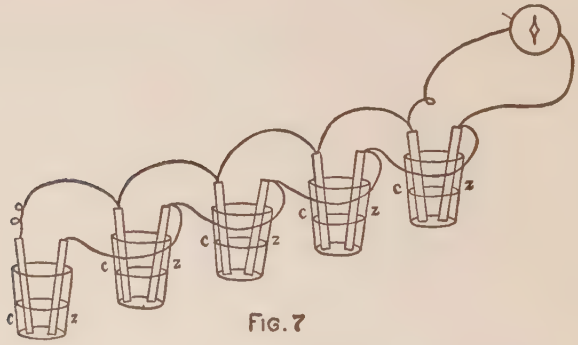


Fig. 7

of plates. The first arrangement is said to be in "series," the second in "parallel." (*Fig.* 7.)

We are now to determine by a few illustrations what advantages may belong severally to these arrangements.

Assume in the above formula $C = \frac{E}{ir+er}$ that the E. M. F. is 1, that the internal resistance is 10, and

the external resistance is 3,000 (3,000 ohms being the average resistance of the human body). By substitution we thus have $C=\frac{1}{10+3000}=\frac{1}{3010}$. If we now take twenty cells arranged in series we shall have $C=\frac{20}{20\times10+3000}=\frac{20}{3200}=\frac{1}{160}$.

If now we take the same number of cells arranged in parallel we shall have by substitution $C=\frac{1}{\frac{10}{20}+3000}=\frac{1}{\frac{1}{2}+3000}1\ \frac{1}{3000\frac{1}{2}}$.

By comparing the two results the enormous difference between the current effect of these two arrangements is discovered. Though in the latter case the internal resistance is reduced to one twentieth of that in the former, yet, as the external resistance is so large, the reduction in the amount of the internal resistance counts for little.

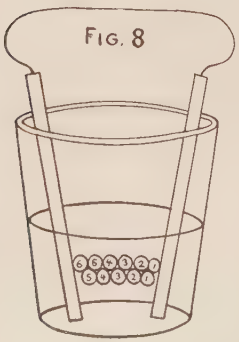
We are thus led to conclude that where the external resistance is large, as in the human body, the proper arrangement of cells is in series. It is evident also that to increase the current it is necessary to make the E. M. F. greater in proportion to the sum of the resistances, and that if the external resistance is great, there is little advantage in decreasing the internal resistance. Thus if we have the equation $C=\frac{1}{2+3000}=\frac{1}{3002}$ we may halve the internal resistance and thus obtain the equation $C=\frac{1}{1+3000}=\frac{1}{3001}$ which gives but a small gain in current; or we may double the E. M. F. and the internal resistance, and thus obtain the following: $C=\frac{1\times2}{2\times2+3000}=\frac{2}{3004}=\frac{1}{1502}$, which is a marked gain.

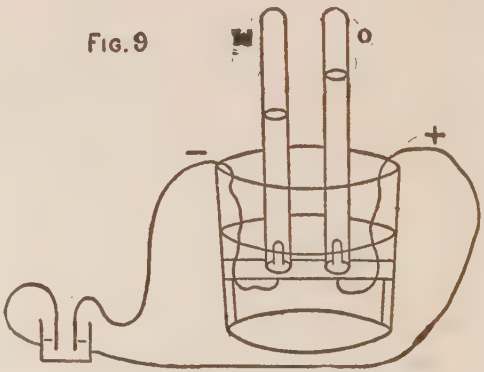
From these illustrations we may draw this conclusion. If we desire to increase the current where

the external resistance is large in proportion to the internal, the number of cells must be increased — arrangement in series. If we desire to increase the current where the external resistance is small, the size of the plates must be increased — arrangement in parallel.

This explains why, where the object to be obtained is heat, as in the electro-cautery, where the external resistance is small, the result is best secured by a few cells arranged in parallel.

"NASCENT" ENERGY. The term "nascent" is applied to an exaggerated activity manifested by an atom or molecule at the time of its dissociation from the atom or group of atoms with which it was previously combined. In this way it is easy to explain, if we adopt the theory of Grotthuss, the appearance of hydrogen upon the copper plate. Thus





in Figure 8, molecule 1 of H_2SO_4 is dissociated, the radicle (SO_4) uniting with an atom of Zn and forming zinc sulphate. The disengaged molecule of hy-

drogen being nascent, attacks the molecule of H_2SO_4 numbered 2, dissociates it and forms the molecule H_2SO_4, indicated in the circle in the lower line (*Fig.* 8) numbered 1. The process continues until the copper plate is reached. Thus the hydrogen appearing at the negative plate is not the original molecule dissociated at the positive plate.

Electrolysis. If two test tubes containing dilute H_2SO_4 be inverted over a water-bath and insulated wires terminating in platinum strips introduced into the test tubes, when the circuit is closed, bubbles of gas immediately arise from the poles and displace the fluid in the test tubes. (*Fig.* 9.) It will be noted that twice as much gas is evolved in one tube as in the other. The gases, as can easily be proved, are oxygen and hydrogen, the hydrogen appearing at the negative pole, and the oxygen at the positive. The electrolytic action of the electric current possesses great interest for the student of medical electricity and deserves to be carefully studied.

If the poles of a direct current battery be introduced beneath the skin for a brief period, blisters are formed about each pole. The serum from the vesicles around the positive pole is acid, while that from the vesicles around the negative pole is alkaline. Thus oxygen, which appears at the positive pole, is by derivation the " acid maker."

CHAPTER III

PHYSICS OF THE INDUCED CURRENT

If a bar magnet be immersed in a heap of iron filings it is found that the filings adhere to the magnet in large masses at the poles. (*Fig.* 10.)

In like manner if a piece of copper wire which carries an electric current be immersed in a heap of

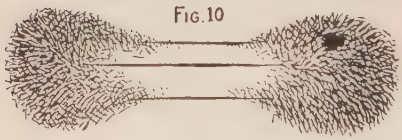


Fig. 10

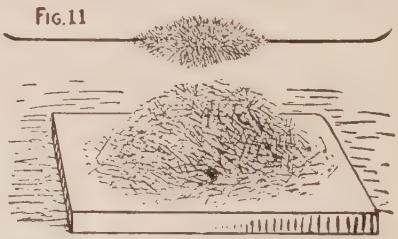


Fig. 11

iron filings, it is found, when the wire is raised, that the iron filings are adherent. (*Fig.* 11.)

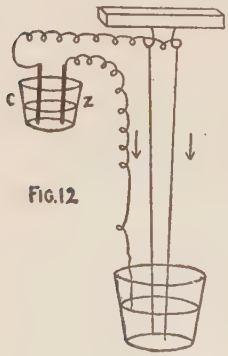


Fig. 12

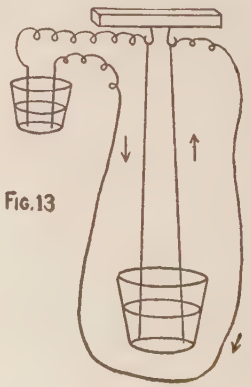


Fig. 13

If an electric current be permitted to divide and flow in the same direction through two copper wires which are parallel, it is found that they attract each other. If,

however, the current flows in opposite directions, they repel each other. (*Figs.* 12 and 13.)

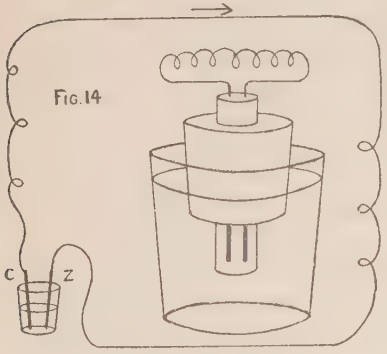
From these experiments we may deduce the law:

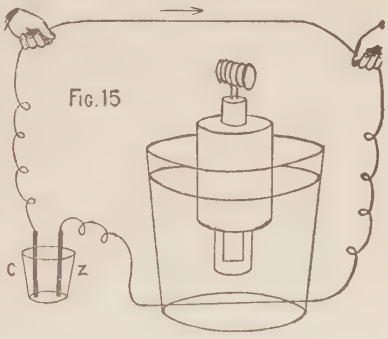
Parallel currents in the same direction attract each other; parallel currents in opposite directions repel each other.

If a copper wire carrying an electric current be placed above and parallel to the helix, or coil of wire, (*Figs.* 14 and 15) of a floating battery, it will be found that the helix will instantly turn so that the currents will flow in parallel planes.

From this experiment we may deduce the law: *Angular currents tend to become parallel and flow in the same direction.*

In like manner if two floating helices be placed end to end and their respective currents allowed to





flow in the same direction, it will be found that the helices attract each other (*Fig.* 16). If, on the other hand, their respective currents are allowed to flow in opposite directions, the helices will repel each other.

Enough has been shown by these simple experiments, and by those already presented, which illustrate the deflections of the magnetic needle, to prove the intimate relation existing between electricity and magnetism, and to lay a foundation for further study of this interesting subject.

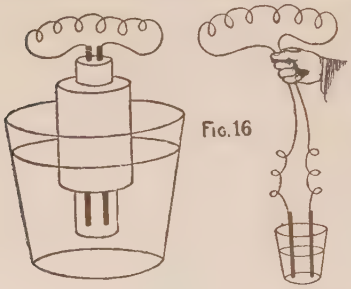
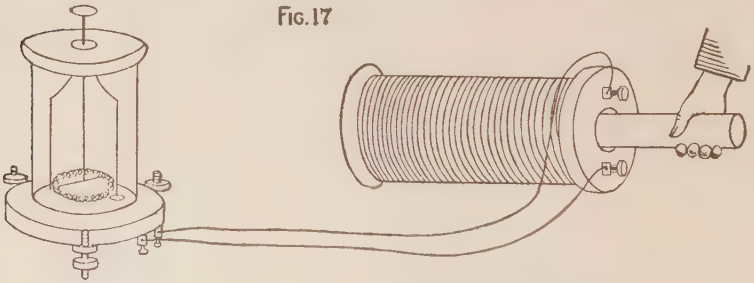


Fig. 16

If a helix is connected with a galvanometer (*Fig.* 17), and a magnetized iron bar is thrust inside, it is found that the needle of the galvanometer is immediately deflected. When the bar is removed it is found that the needle is again deflected, but in the

Fig. 17



opposite direction, and in each instance it is observed that the needle resumes its normal position when the motion of the magnet ceases. From this experiment we may infer *that the electrical energy excited in the coil is at the expense of mechanical energy.*

If instead of introducing a permanent magnet within the helix we introduce a bar of soft iron, and

move back and forth over one extremity of the soft iron one of the poles of a permanent magnet, the needle of the galvanometer is violently agitated, turning in one direction at each approach, and in the opposite direction at each departure, of the magnet. If the experiment is repeated with the opposite pole, the currents, as shown by the galvanometer, are reversed.

If now instead of introducing into the helix a permanent magnet or a bar of soft iron influenced, as described above, by a permanent magnet, we introduce another helix connected with a battery, and move it back and forth, we obtain precisely the same results.

Now it is to be observed that the current flows in the secondary coil only during the motions of the primary coil, and delicate measurements have proved that the total quantity of induced electricity depends upon the rapidity of movement, not upon the time required to make the change. Hence we derive the law: *In any induced current the E. M. F. at any instant is proportionate to the rapidity of the relative change at that instant.*

If instead of introducing and withdrawing the primary coil we allow it to remain stationary within the secondary coil and close and open the primary circuit, we obtain exactly the same phenomena as were obtained with a permanent magnet or with a to and fro motion of the primary coil. It is in effect the same thing. We may summarize the results thus far obtained as follows: *When a current in a primary coil is made, the induced current has a direction opposite to that of the primary.*

When a current in a primary coil is broken, the induced current has the same direction as the primary.

Extra Currents. The principles above explained apply not simply to conductors which are detached from each other, but to neighboring portions of the same conductor. When, for example, a circuit is closed the current does not immediately reach its greatest intensity, because a current opposite in intensity is at once developing in the same conductor, which tends to diminish the intensity of the inducing current. On the other hand, when the circuit is opened, the induced current being in the same direction tends to increase the intensity of the primary current.

Induction Coils. If a piece of soft iron (*Fig.* 18) or a bundle of soft iron wires be inserted within the primary coil, it is found that the magnetization and demagnetization of the core greatly increase the intensity of the secondary currents.

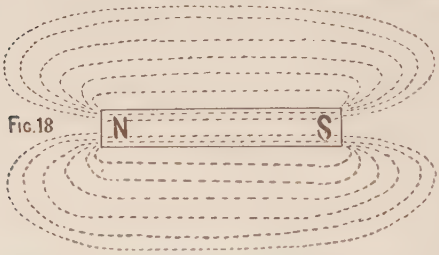
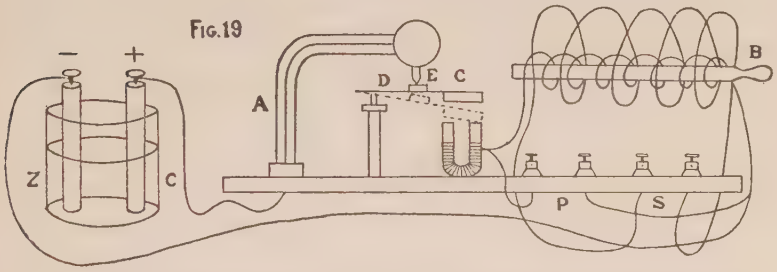


Fig. 18

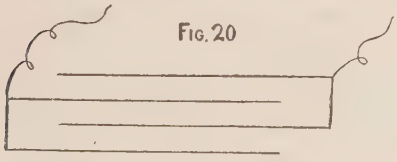
The core is further utilized to make and break the current of the primary coil automatically, or a separate electro-magnet is provided for this purpose, as shown in Figure 19. When a current passes through the primary wire A, the soft iron in the electro-magnet F is magnetized. The magnetism thus excited attracts the soft iron hammer C mounted upon the spring D, thus opening the circuit. The circuit being now

open, the magnet loses its magnetism, the hammer returns to its former position, again closing the circuit, and thus repeating the process. Instruments



constructed upon these principles are called induction coils.

Rhumkorff's Coil. If an induction coil is provided with a condenser it is called a Rhumkorff's coil. A condenser (*Fig.* 20) may consist of two or more layers of tin foil separated by paraffin paper. Alternate layers are connected with the positive and the negative pole of the battery and constitute a shunt from the primary coil. The purpose of this addition is to provide an escape for the extra currents above described, which find it easier to pass into the condenser than to leap across at E (*Fig.* 19), vaporizing the points of contact, and thus prolonging the time occupied in breaking the circuit. Moreover, as the condenser discharges into the primary coil, and in an opposite direction to the current



flowing in the coil, it demagnetizes the core and promotes rapidity of action in the vibrator.

We have thus far presented the essential principles underlying the action of direct and induced currents. These principles have been set forth inductively; that is to say, no principle has been announced without first presenting the facts by way of a simple experiment from which the student may himself deduce the principle underlying the facts presented. For purposes of condensation, self-explanatory terms have not been defined, but all that is essential in the physics of these currents has been presented, and the student who has acquired them has laid the foundation for an intelligent study of medical electricity.

In coils wound for medical purposes it is customary to use in the primary coil a wire having a diameter several times larger than that used in the secondary coil. Naturally, therefore, the length of wire employed in the secondary coil considerably exceeds that used in the primary. In general, it may be said that the E.M.F. of the secondary coil increases with the number of turns of the wire. This, however, is modified by the increased resistance offered by the increased length of the wire and also by the presence of induced or extra currents.

Measurements of Induced Currents. This is not so simple as the measurement of direct currents, yet several instruments have been invented for this purpose, notably those of DuBois Reymond, and Giltay, of Delft, Holland. An instrument called

the " Faradimeter " has been designed by Dr. Sloan, of Glasgow, whose purpose is to measure the currents of medical induction coils, and another instrument has been invented by the late Lord Kelvin for a similar purpose.

Regulation of Induced Currents. If a hollow cylinder of brass or copper be introduced between the primary coil and the bundle of soft iron wires constituting the core, it will be found that the E. M. F. of the current is greatly reduced. When the cylinder is gradually withdrawn there is a corresponding increase in the strength of the currents. This is due to the fact that the cylinder cuts the lines of magnetic force of the core, and its gradual withdrawal permits them to exert their full energy. This is the method commonly employed for the regulation of currents in small medical coils.

A rheostat is a device for furnishing a variable resistance. It is of two kinds, series and shunt. The former is not now extensively used, the shunt rheostat usually taking its place. The series rheostat reduces the amount of current without materially affecting the voltage. The shunt rheostat is practically the only method of reducing voltage. Figure

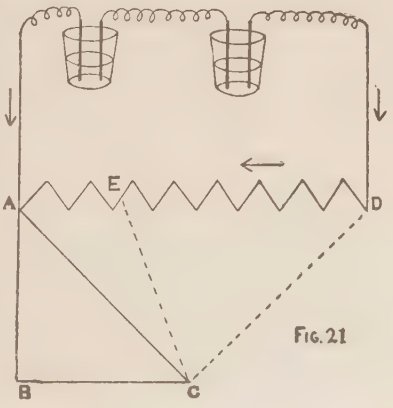


Fig. 21

21 is a diagram illustrating the principle underlying the use of the shunt resistance. A D represents a coil of wire on a surface covered with graphite, A B C a stationary wire, and A C a movable wire which may be made to traverse A D. The patient being placed at C and the movable wire carried to E, it is readily seen that the pressure at C will depend upon the ratio which the resistance of A E bears to the resistance offered by the loop A B C E. If the resistance of A E is greater than that offered by the loop, the patient will get most of the current.

Current Collector. Figure 22 represents a plan for successively introducing into the circuit the cells of a direct current battery. Here the six cells joined in series are connected with six studs fitted upon a plate above the cells. When the lever is placed upon the stud marked O, it is evident that no current will flow. When it is moved to stud 1, 2, 3, 4, 5, or 6 respectively, it is clear that the number of cells will be thrown into the circuit between the binding screws, which is indicated by the number of the stud upon which the lever is resting.

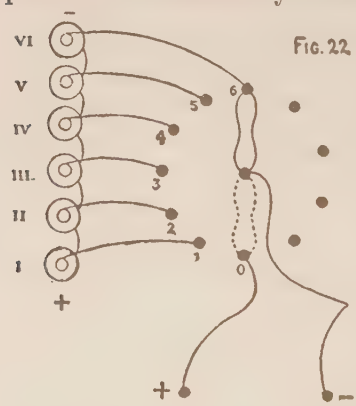


Fig. 22.

The enormous importance of a thorough understanding of units of electrical measurement may be

illustrated by an example. Let it be desired to know at any moment what resistance the current is meeting in the tissues of the patient. Assuming that the pressure is forty volts and the current strength is ten milliamperes, or one one-hundredth of an ampere, we then have by substitution in the equation $R=\frac{E}{C}$, $R=\frac{40}{\frac{1}{100}}$, or four thousand ohms, which represents the resistance of the tissues under the conditions given. It must therefore be evident that a rheostat in a medical battery should exceed in the resistance it interposes the amount of resistance likely to be met in the tissues of the patient. A rheostat which from its construction is likely to interpose a variable resistance, due either to a wearing away of the material constituting it, or to a marked elevation of temperature, which decreases the conductivity of the conductor, is therefore open to serious objection. Consequently,

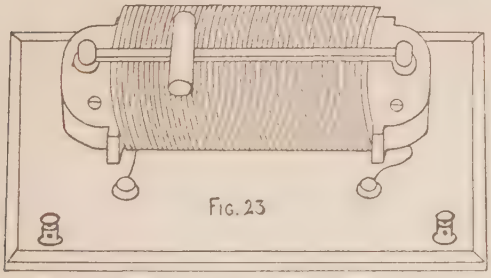


FIG. 23

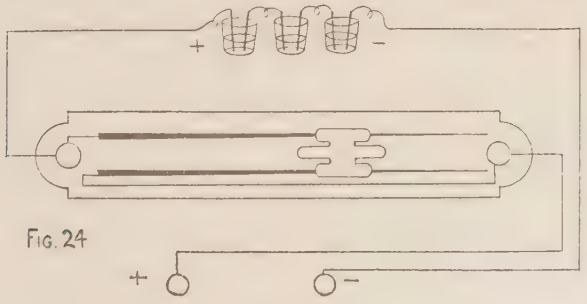


FIG. 24

a wire rheostat is to be preferred to a graphite rheostat as ordinarily constructed.

Figure 23 represents a rheostat consisting of an uncovered german silver wire helix with a metal traveler sliding upon a metallic arm. The current enters at one end and leaves by the metal traveler.

Another type of rheostat is represented in Figure 24, in which two parallel tracks of graphite are connected by a sliding metal bridge. By altering the position of the bridge a greater or less length of graphite is brought into the circuit.

Still another type of graphite rheostat is made by brushing graphite upon a slate surface and varying the amount of resistance by the movement of a lever upon the badly conducting graphite.

CHAPTER IV

PHYSIOLOGY OF THE DIRECT CURRENT

Polar Effects, Phoresis, Interpolar Effects

Having in the two previous chapters studied inductively the physics of the direct current and induced currents, we are now to consider by the same method the effect of the direct current upon animal tissue.

Polar Effects.— If a current of about two hundred milliamperes be allowed to pass into a piece of beef muscle for two or three minutes by means of two steel needles, one connected with the positive and the other with the negative pole of a direct current battery, a peculiar hissing noise is heard which appears to proceed from the negative pole, and is caused partly by the escape of bubbles of hydrogen along the track of the needle connected with that pole. (*Fig.* 25.)

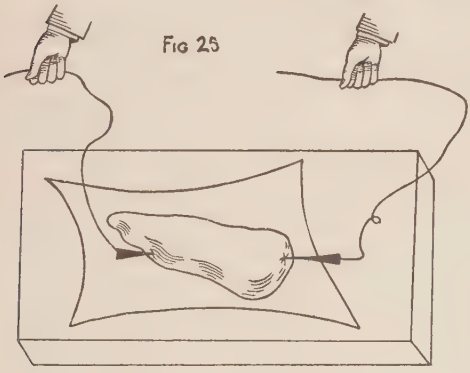


Fig 25

Upon opening the circuit it is found that the needle connected with the negative pole is easily withdrawn, while that connected with the positive pole adheres to the tissues, and is withdrawn with difficulty.

If an incision be made into the muscle around the negative pole it is found that the tissues are soft and infiltrated, to some extent destroyed, and of darker color, and that the needle occupies a cavity filled with fluid and bubbles, and remains bright and untarnished.

A similar incision into the muscle around the positive pole reveals hardened tissues, which have been darkened by the iron dissolved from the needle, and dehydrated by the gas which is developed by the current. The needle is darkened and corroded.

If a piece of reddened litmus paper be placed in the froth surrounding the needle connected with the negative pole and the circuit again closed, the paper will soon turn blue; in like manner if a piece of blue litmus paper be placed in contact with an uncorroded platinum needle connected with the positive pole, the paper will turn red.

From this simple experiment we observe a number of important differences between the behavior of the positive and the negative pole, which may be briefly summarized thus:

(1) The *fluids about the positive pole are acid; those about the negative pole are alkaline.*

(2) *The gas generated at the positive pole is*

oxygen; that at the negative pole is hydrogen. (*Vide Chap.* II, Electrolysis, *Fig.* 9.)

(3) *The tissues around the positive pole are hardened by acids; the tissues around the negative pole are partially destroyed by alkalies.*

(4) It was noted that the needle attached to the positive pole had a tendency to adhere to the tissues; the needle connected with the negative pole was easily withdrawn. The former, therefore, had a dehydrating effect upon tissue, the latter an infiltrating effect. From this we may provisionally infer *that the positive pole in living tissue lessens congestion and checks hemorrhage; the negative pole improves nutrition and dilates circulatory channels.*

Therefore,

(5) *The positive pole is a vasomotor constrictor; the negative pole is a vasomoter dilator*, congestion or stasis being due, at least partially, to a relaxation of vasomotor control, and hemostasis, in some measure, to increased tonicity of vasomotor nerves.

If it be objected that it is not safe to apply conclusions drawn from the behavior of the electric current on dead tissue to its action upon living tissue, it may be replied that experimental research in electrophysiology would seem to warrant the soundness of the inferences contained in (4) and (5).

Phoresis.— If two porous cups be placed in a vessel containing water, and filled to an equal height with the same fluid, and the positive pole of a direct current battery introduced into one of the cups and the

negative into the other, upon closing the circuit it will be observed, after a short time, that the fluid in the cup containing the positive pole has been reduced, while that in the cup containing the negative pole has been increased. (*Fig.* 26.)

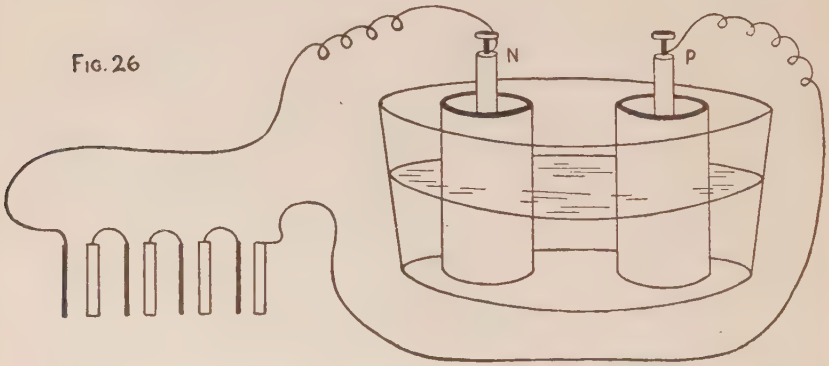


FIG. 26

That this is not purely an osmotic process, that is to say, the passage of a fluid of lighter density through an animal membrane into a fluid of heavier density, may be easily shown by placing the positive pole in a fluid of heavier density, which will then be carried in an opposite direction into the fluid of lighter density. This physical transference of fluid by the electric current is called *phoresis*, and is shown experimentally above in the dehydration of tissues around the positive pole in the experiment with the beef muscle.

It was noted above in the same experiment that the needle attached to the positive pole was no longer bright and shining, but was dark and corroded, and that the tissues in the immediate neighborhood were

of a darker color. If a copper electrode had been used, the tissues would have been stained green. Platinum alone seems to resist the chemical action manifested at the positive pole. This destructive process, in consequence of which ions are detached from the positive pole, and associated with other ions similarly detached from their fellows, forming new compounds called oxides and oxychlorides of the metals attacked, is called *electrolysis*, which by derivation is a tearing apart by electricity, and is identical with the process described in Chapter II, on the physics of the direct current, in which water is decomposed into its constituent parts, though in that case new compounds were not formed by the detached ions.

Ions are divided into two classes — electro-positive and electro-negative. The former are attracted to the negative pole and are therefore called *kations;* the latter to the positive and are therefore called *anions*, as ions of like polarity repel, and those of unlike polarity attract each other. In general the metals, hydrogen, and the alkalies are electro-positive; oxygen, chlorine, and the acids are electro-negative. In the above experiment, if we put a solution of potassium iodide in one cup and a mixture of starch and water in the other, and drop a wire attached to the negative pole in the former, and a similar wire attached to the positive pole in the latter, upon closing the circuit we shall note after a while a blue color in the cup containing the starch water, due to the electrolytic decomposition of the potassium

iodide, and the phoresic transfer of the dissociated iodine, which strikes a blue color with the starch.

From these experiments we may infer that phoresis is a double process and consists of

(1) A physical transference of fluids as above illustrated, and

(2) An electrolytic decomposition of substances through which the current passes.

We have thus explained a further difference between the action of the positive and the negative pole, *viz:*

(6) *The positive pole is dehydrating and desiccating; the negative pole is infiltrating.*

One need, therefore, never be at a loss in selecting the pole upon which a medicament is to be placed for medicamental phoresis. If it be desired to introduce cocaine hydrochloride into the tissues, the solution should be placed upon the positive pole, as the alkaloidal base is electro-positive, and an electro-positive ion is attracted to the negative pole. If, however, a solution of potassium iodide is chosen for diffusion, it should be placed upon the negative pole, because iodine is electro-negative, and consequently seeks the positive pole.

Katelectrotonus and Anelectrotonus.—As a possible, though not adequately demonstrated consequence of the phoresic action of the direct current, we have the phenomenon called *katelectrotonus*,

which is the increased excitability of the tissues in the neighborhood of the negative pole.

A corresponding decrease in the excitability of the tissues in the neighborhood of the positive pole is called *anelectrotonus*.

While the infiltrations of the tissues about the negative pole may be a partial explanation of the increased sensibility at that point, it has been urged that in animal tissues an increased alkalinity accompanies inflammations, while an acid condition leads to sedation and anesthesia, because the latter precedes a a lowered tonicity, and eventually leads to destruction of the parts affected.

To the differences, therefore, already noted in the action of the positive and the negative pole we may consequently add another, viz:

(7) *The positive pole is sedative, the negative is irritating.*

Elaborate experiments with the galvanic current have proved that the positive pole in strengths above fifty milliamperes is bactericidal, though with lower strengths it is not only non-bactericidal, but, through the addition of oxygen to cultures of bacteria, may even promote their growth. As, however, below these strengths it is very easy to employ metallic phoresis, it still remains true, for practical purposes, that the positive pole is bactericidal. Similar experiments have proved that the negative pole exerts no influence upon the vigor of cultures. We may, therefore, add a further deduction, *viz:*

(8) *The positive pole is bactericidal, the negative pole is non-bactericidal.*

Interpolar Effects.— Having now considered more particularly the polar currents, let us turn our attention to what takes place in the interpolar regions or the regions between the poles.

Experiments, which unfortunately are too elaborate for reproduction in the space assigned to these chapters, prove conclusively that in tissues of variable resistance, such as those constituting the human body, the currents do not pass in straight lines between the poles, but in lines similar to those drawn in Figure 27.

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Immediately beneath the poles and extending for some distance into the tissues, the effects described above as characteristic of the poles may be expected. In the interpolar spaces the effects to be expected would depend upon electrolysis, phoresis, vasomotor stimulations and contractions in non-striated tissues produced by heavy currents.

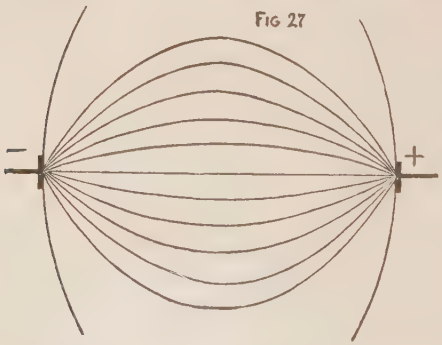


Fig 27

The fluids of the body contain in solution sodium chloride, calcium phosphate, calcium carbonate, magnesium phosphate, potassium chloride, sodium and potassium phosphate, sodium and potassium carbonate, and sodium and potassium sulphate. It can therefore very readily be seen that, in

traversing the human tissues saturated with fluids holding the above salts in solution, the electric current must of necessity expend itself largely in dissociating molecules from their usual combinations, rendering the detached ions "nascent," and thus increasing the activity of metabolic processes, which in many conditions of impaired health are below their normal level.

Take, for example, sodium chloride. In the blood it is nearly as abundant as all the other mineral ingredients together. One of the most frequent chemical reactions in the tissues is doubtless represented by the following equation: $H_2O + NaCl = HCl + NaOH$, in which hydrochloric acid and sodium hydrate are produced by the interchange of the molecules of water and common salt. This may fairly be taken as a type of chemical interchange produced by the interpolar action of the electric current, and, as it is believed that chemical affinity and electrical attraction are identical, it may readily be seen that the disintegrations and recombinations of salts in solution in the tissues are a necessary accompaniment of the progress of the electric current through the body, the nascent energy thus developed heightening metabolism and promoting elimination.

There is, however, not simply a disintegration and recombination of molecules as typified in the above reaction, but there is also an actual physical movement of fluid in the interpolar spaces under the impelling influence of the electric current. The interpolar action is therefore made up of the two

elements constituting phoresis, namely, physical transfer of fluids and electrolytic decomposition of substances.

Or, we may take, as a further illustration, the salt, potassium chloride, which is abundantly found in the tissues, especially in the muscles. Under the influence of the electric current we may suppose that the following reaction takes place: $KCl + H_2O = HCl + KOH$, in which we obtain one molecule of hydrochloric acid and one molecule of potassium hydrate.

Or, if we consider sodium sulphate, of which a somewhat minute proportion exists in the tissues, we shall obtain the following electrolysis: $Na_2SO_4 + H_2O = H_2SO_4 + Na_2O$, in which the new products are sulphuric acid and oxide of sodium.

The Na_2O, however, being somewhat unstable, we may assume that by combination with another molecule we obtain the following reaction: $Na_2 + H_2O = 2NaOH$, or two molecules of sodium hydrate.

In these illustrations of interpolar processes we note the formation of acids and alkalies, which tend

Fig. 28.

by their attractions to move toward the poles for which they have an affinity, the alkalies proceeding to the negative pole, the acid radicles and acids to the positive pole.

If the poles of a direct current battery be placed upon the abdomen (*Fig.* 28), the positive over one rectus muscle and the negative over the other, and an interrupted current of sufficient volume be allowed to pass through the circuit, it will be noted at once that the muscles powerfully contract.

What is true of striated muscular tissue is equally true of the non-striated, since both varieties are susceptible to electrical stimulation, so that we may fairly infer that an interrupted direct current of suitable strength, by its contractile effect upon muscular tissue, would relieve stasis and promote drainage in the lymphatic spaces, stimulate the muscular coats of arteries and intestines, and generally promote metabolism.

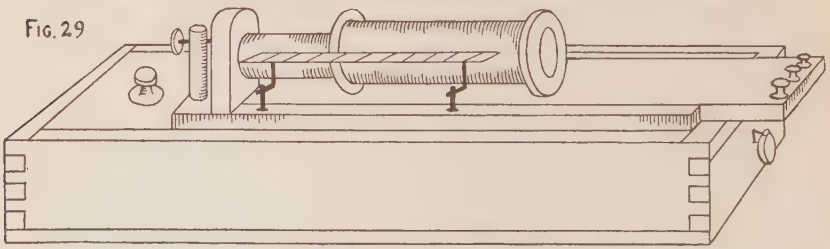
It will be noted in bringing this chapter on the physiology of the direct current to a close, that probably all the conclusions reached have been inferred from the simple experiment with the beef muscle, taken in conjunction with the principles of electro-physics already explained, and that it has not been a difficult task to ascertain facts of the utmost importance in electrotherapeutics by the employment of simple and inexpensive methods.

CHAPTER V

PHYSIOLOGY OF THE INDUCED CURRENT

We are now to endeavor to ascertain the effects which induced currents exercise upon living tissues. For this purpose it is well to employ a coil which enables us to note with some accuracy the intensity and quantity of currents delivered. A coil in which variations in the intensity of the current are indicated on a scale corresponding to the position of the secondary coil with reference to the primary, possesses advantages over one in which intensity is varied by the movement of a hollow cylinder over the core. Such an arrangement is called a "sledge," or sliding coil (*Fig.* 29), because the secondary is

Fig. 29



movable with reference to the primary coil. If now we undertake to study the properties of currents delivered from the secondary winding of such a coil, by inserting needles attached to the positive and

negative poles into a piece of beef muscle, and pursue the same order as was followed in the preceding study of the direct current we shall find:

(1) *That there is no marked difference in the reaction of fluids surrounding the poles.* If the poles of the secondary winding be placed in a mixture of iodide of potassium and starch, the blue color caused by the action of the dissociated iodine upon the starch may appear at both poles.

(2) *That there is no collection of gas at either pole.* When platinum terminals, connected with the secondary poles of an induction coil, are immersed in water, a momentary electrolysis takes place. The dissociated oxygen produces an oxide of platinum which is then reduced to metallic platinum by combination with the nascent hydrogen. This process takes place at both poles, so that both become covered with powdered platinum. As platinum has the power of occluding oxygen, it is probable that the gray appearance of the poles is due to the conversion of the metal into its spongy form.

(3) *That there is no chemical or noticeable chemical effect exerted upon the surrounding tissues.*

(4) Employing the apparatus used in Chapter IV (*Fig.* 26), "Physiology of the Direct Current," we discover that there is no physical transfer of fluids between the poles.

Employing the apparatus used in Chapter II (*Fig.* 9), "Physics of the Direct Current," we discover that there is no permanent separation of water into its constituent elements and therefore no permanent

electrolysis. Therefore, as both the elements of physical transfer and electrolysis of fluids are lacking, *there is no phoresis, and consequently no noticeable desiccating or dehydrating effect at either pole.*

(5) Experiments may be made tending to show that induced currents exert no appreciable effect upon the growth of cultures. *Therefore, coil currents are without bactericidal effect.*

While there has been a general agreement upon this proposition, Spilker and Gottstein have reported experiments in which strong and long-continued induced currents, even where heating effects were guarded against, produced a destructive effect upon the growth of cultures.

The above experiments may be thus summarized: The induced current exerts no considerable chemical effect upon animal tissues, and so far as they are manifest at all are, for therapeutic purposes, quite negligible. Admitting that induction currents from a large Rhumkorff coil may produce chemical effects, yet these currents are of such volume and intensity as to preclude their use for therapeutic purposes. In coils whose currents are suitable for direct application to the human body, the swift change of polarity tends to destroy chemical action. This lack of continuity, in which relatively long intervals occur between the crest of successive waves, during which no currents or currents of slight intensity and quantity are flowing, still further reduces chemical action.

In this discussion we are confining ourselves to

the effect of the induced current. The primary current is a battery current interrupted by the vibrations of a spring, and is a unidirectional current, modified by the phenomena of extra currents. Such a current readily electrolyzes iodide of potassium, producing a brown cloud at the positive pole, or a blue color if the iodide of potassium has been first mixed with starch. The induced current is not unidirectional. It is made up of a current at the make and a current opposite in direction at the break of the circuit. When used for therapeutic purposes induction coils deliver currents of high intensity but small volume. As chemical action is dependent upon amperage rather than voltage we have an additional explanation for the slight chemical effect of induction currents.

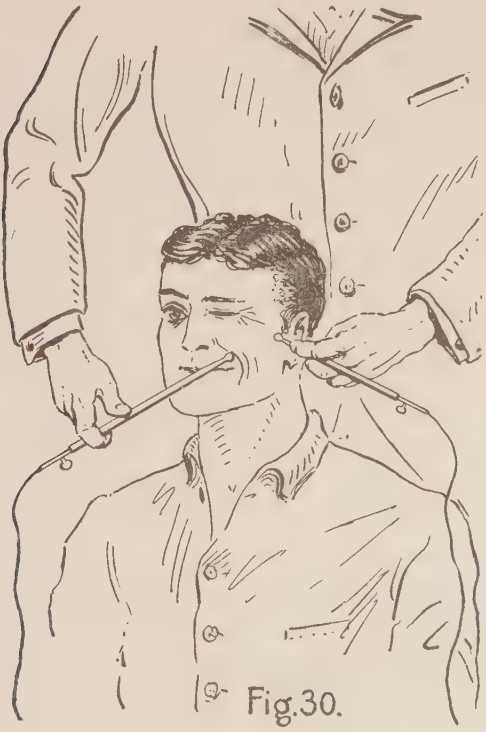


Fig.30.

We must, then, look for the physiologi-

cal effects of induced currents in a different direction. If we take into each hand a metal electrode attached to a coil, we detect the presence of a current. This may be called " stinging," "numbing," " burning," or under certain conditions perhaps " soothing."

If one pole of an induction coil be placed immediately in front of the ear and another near the corner of the mouth on the same side of the face, it will be noted that the mouth is drawn to one side and the eye is closed. (*Fig.* 30.) This is evidently due to the stimulating effect of the induced current upon the facial nerve and the muscles which it innervates, or directly upon the muscles themselves.

These experiments are sufficient to show that while induced currents do not produce appreciable chemical effects, they excite marked sensory and motor effects. Such other effects as may be produced by these currents, as for instance, improved metabolism, increased activity in glandular processes, and larger elimination of toxic products, are probably due to the excitation and passive exercise of nerve and muscular tissues.

While we are obliged to deny a marked chemical polarity to induced currents, used for therapeutic purposes, inasmuch as an alternating current quickly neutralizes the tendency toward chemical action, yet there is a sensible difference between the positive and the negative pole. The negative pole is more irritating to the sensory nerves than the positive pole. This is due to the more abrupt rise of the curve when the current is broken. So marked is the difference between the

effect produced at the positive and the negative pole that, *physiologically*, induced currents may be regarded as unidirectional, owing to the preponderating influence of the negative pole.

Physiological Measurements of Induced Currents.— In Chapter III, "Physics of the Induced Current," a brief reference was made to instruments invented for the purpose of measuring induced currents. These are designed to measure the electromotive force of the currents delivered from induction coils and are successful in accomplishing this end, but unfortunately the results thus obtained in the testing of different coils do not correspond with the physiological responses of living tissue. These instruments, therefore, are for medical purposes of little value.

Moreover, the electromotive force of induction coils varies with the amount of resistance interposed between the terminals.

Such measurements, therefore, do not assist us much in determining the effects of induced currents, because the relation between electromotive force and physiological effect is evidently complicated by other factors, as, for instance, rapidity of interruptions of the current, presence or absence of the core, position of the secondary coil with reference to the primary, relation of diameters and lengths of wires in primary and secondary coils, and finally strength of the battery exciting the primary coil.

Curves of Induced Currents.— That each one of these factors has an influence in determining

the physiological effect of induced currents is not a matter of conjecture, but can readily be proved by a study of the curves produced by the same instrument under the different conditions named above, and these different curves are found to correspond to differences of physiological effect.

These curves are obtained from the tracings of an oscillograph on a moving photograph plate and vary widely from one another, according as one or more of the factors above mentioned are altered or eliminated. One or two illustrations will serve to explain the effect of a variation in one or more of the factors determining the physiological effect of induced currents.

Figure 31 represents a tracing of a curve of a coil in which one third of the secondary winding is

FIG. 31.

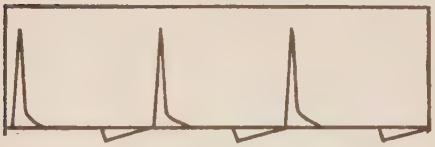
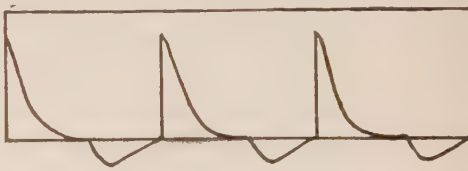


FIG. 32



used. The waves above the line represent the current at break, those below, the current at make, and the interval between represents the time between discharges. The tracing is read from left to right.

Figure 32 represents the current curve of the same coil when the whole secondary winding is employed. The use of the oscillograph method of comparison of

curves has shown that a coil giving about one hundred interruptions per second with individual waves lasting one one-thousandth of a second and intervals nine times as long is best suited for muscular stimulations.

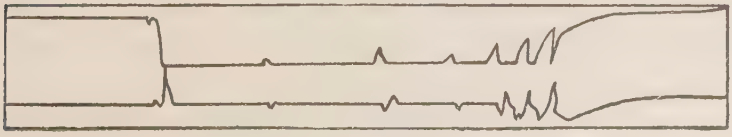
Sensory Effects.— By using the same method for studying the curves of induction coils, the interesting discovery has been made that the painful effects of induced currents are proportional to the length of their curves. Thus a wave that lasts one two-hundredth of a second is excessively painful, while one that lasts one four-hundredth of a second is not unpleasant.

Now it is found experimentally that the production of long waves accompanies a high degree of self-induction, to which reference has been made in Chapter III, "Physics of the Induced Current," under the subhead *Extra Currents*. These currents are found to be greater in coils where there is a great length of wire in the primary and secondary coils, much iron in the cores, and the current is interrupted by an auxiliary electromagnet.

Motor Effects.— While the effect upon sensation is influenced by the length of the wave, the contraction of voluntary muscles is not thus modified.

Mechanical Interrupters.— (*Fig.* 33.) A study of the above tracing makes it evident that the

Fig. 33



interrupter has not always succeeded in making contact. The failure to make sharp, clean interruptions is indicated by slight elevations and depressions to the left of the waves. This evident imperfection in interruption of the current, which, owing to the irregularity in wave lengths thus produced, may occasion disagreeable sensory effects, has led to the use of mechanical interrupters, which possess many advantages over the ordinary vibrating hammer. These advantages are:

(1) Both the quality and the intensity of the current can be measured.

(2) The frequency of interruption can readily be determined, and, finally,

(3) The stinging effect upon the sensory nerves can be avoided by producing impulses of short duration.

Anesthetic Effects of the Induced Current. — If the terminals of a secondary coil producing one hundred or more interruptions per second, and having a proper relation between its wave length and interval of rest as described above, be applied to the trunk of a nerve having a cutaneous distribution, a sense of numbness will soon appear in that area in addition to the effect felt at the point of application of the electrode. This is a true anesthesia, both tactile and painful sensations being partially obliterated. When the current is cut off a glow accompanied with perspiration frequently follows. This is in all probability a purely mechanical effect. A similar effect is obtained from the positive pole

of the direct current, due, however, largely to its chemical action.

Counterirritation of Induced Current.— If a wire brush electrode attached to one of the terminals of the secondary winding of an induction coil be applied to the skin, after a time it will be found to be reddened, somewhat as it appears after an application of mustard or mustard water. This is a familiar effect of coil currents.

Summary and Comparison of Direct and Induced Currents.— We are now in a position to summarize the effects produced by induced currents as being (1) sensory, which are usually painful, but under some conditions sedative, (2) motor, (3) counterirritant.

It is true that sensory, motor, and counterirritant effects are not confined to the induced current, but are manifested also by the direct current; but with the latter, sensory effects occur not only at the opening and closing of the current, but also during its passage. These effects are due to the chemical action of the direct current and are felt chiefly at the negative pole. The motor effects of the direct current are due principally to interruptions, while counterirritation results from chemical action.

It is thus very apparent that the range of effects produced by induced currents is much smaller than that produced by direct currents; for the interrupted direct current, that is, the so-called voltaic alternative, is capable of taking the place of induced currents to a very great extent, and at the same time lends itself readily to careful measurement.

The problem of measurement of induced currents is, indeed, up to the present moment quite insuperable; not because the physical problem is so difficult, but because physiological responses to induced currents do not bear a proportional relation to the variations of these currents. It might therefore well become a question, whether, in the interest of scientific accuracy, it would not be better to use the interrupted direct current, or at least an induction current, in which the interruptions, instead of depending upon the uncertainties of a vibrating hammer, are produced by a mechanical interrupter entirely independent of the current produced by the coil. Against this suggestion may be urged the cheapness and portability of induction coils as ordinarily constructed, which have been, in effect, as contrasted with the direct current battery, their chief recommendation to popular favor.

Moreover, while an induced current will produce contractions only in muscles which are in healthy relation to the motor nerve governing them, a direct current will produce contractions even when the nerve is cut, and will continue to do so even after there has been extensive degeneration in muscular tissue. Consequently, where there is atrophic spinal or peripheral paralysis the direct current should be employed.

CHAPTER VI

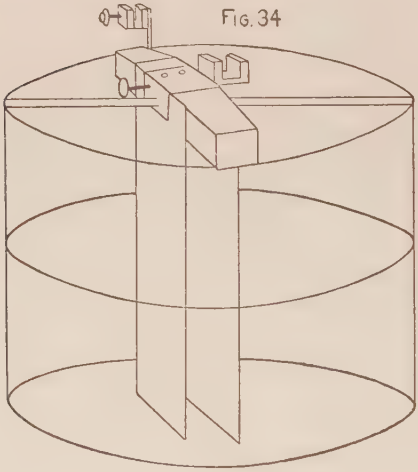
PRIMARY BATTERIES. STORAGE OR SECONDARY BATTERIES. DYNAMO MACHINES. TRANSFORMERS

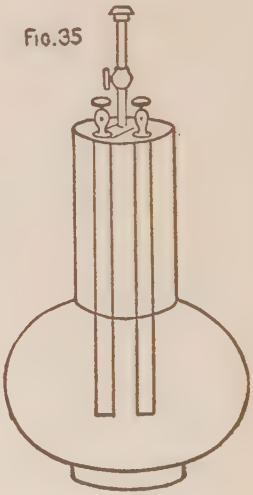
Polarization.— A great reduction in the effectiveness of voltaic cells is occasioned by the polarization of the negative plate. We have already seen in Chapter II, on the physics of the direct current (*Fig.* 9), that hydrogen appears at the negative plate. These bubbles after a time completely cover the plate and ultimately destroy the difference in potential between the two plates. This reduction is accomplished in two ways. In the first place hydrogen is a poor conductor, and in the second place, as hydrogen is electropositive, it forms with the copper a galvanic couple producing a current almost as strong as that between zinc and copper, and in an opposite direction. To get rid of these bubbles many devices have been adopted, which may be classified as (*a*) mechanical; (*b*) chemical; (*c*) electro-chemical.

(*a*) Mechanical Devices.— Under this head may be included the brushing away of the hydrogen bubbles as they appear on the negative plate, or carrying air through, or revolving the plate in, the exciting fluid. These methods are unsatisfactory, and as a partial solution of the problem Smee's

battery (*Fig.* 34) was constructed, in which a silver plate covered with a rough surface of finely divided platinum is substituted for the copper plate. From these points the hydrogen bubbles readily escape, but not with sufficient rapidity to maintain a powerful current.

(*b*) Chemical Devices.— In this method a highly oxidizing substance, such as bichromate of



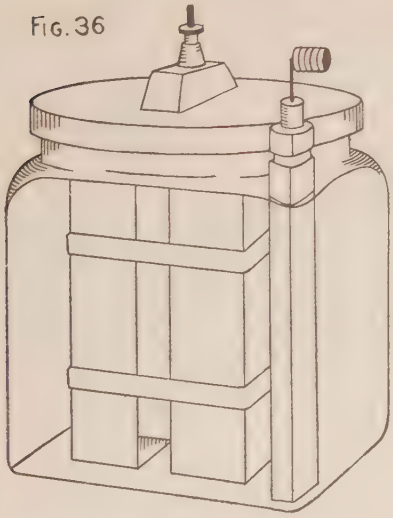


potassium, bleaching powder, or nitric acid, is added to the solution to oxidize the hydrogen as soon as it is formed. The bichromate battery (*Fig.* 35) illustrates this principle. To make the solution five fluid ounces of sulphuric acid are poured into three pints of water, and when this is cooled six ounces of powdered bichromate of potassium are added. This solution will attack copper; therefore carbon is substituted and as it will also attack zinc, a rod is pro-

vided by which the zinc plate may be raised out of the liquid when the battery is not in use. This battery gives a strong current when used for a short time, but it is not very successful in checking polarization.

The Leclanché battery undertakes by the same method to overcome polarization. It employs zinc and carbon elements, combining the latter with powdered binoxide of manganese — a substance which

Fig. 36



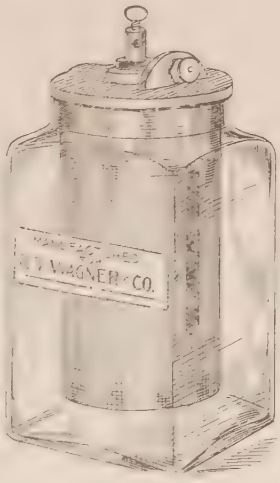


Fig. 37.

slowly yields oxygen and thus destroys the hydrogen bubbles — and an aqueous solution of sal ammoniac.

One form of this battery (*Fig.* 36) places the zinc element between two compressed prisms of carbon and binoxide of manganese, and a later type (*Fig.* 37) omits the use of the latter entirely. As this battery is used chiefly upon so-called open circuits for house and hotel annunciators, for burglar alarms,

etc., where occasional or momentary use is required, it serves its purpose admirably, demanding little attention and furnishing a current of about 1.5 volts.

(*c*) ELECTRO-CHEMICAL DEVICES.—This method takes advantage of the power which the electric current possesses of depositing metals from solutions of their salts upon the negative plate. For this purpose double cells are required containing different fluids. Such batteries effectually prevent polarization and furnish uniform and steady currents.

This principle is well illustrated in the Daniells battery. There are many types of this battery, but

FIG. 38

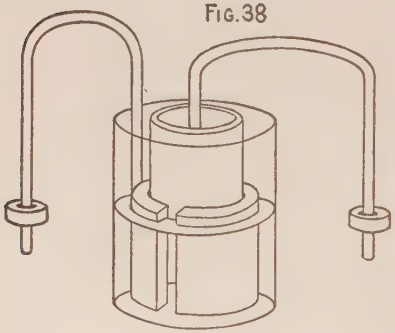


Fig. 39.

the principle is the same in all. For convenience we describe a type (*Fig.* 38) in which the zinc stands in a porous cup, containing dilute sulphuric acid.

Outside of the porous cup is a cylindrical strip of copper standing in a solution of sulphate of copper, the whole being contained in a glass receptacle, When the current is closed, the acid attacks the zinc, forms zinc sulphate, and liberates hydrogen, thus:

$$Zn + H_2SO_4 = ZnSO_4 + 2H.$$

The liberated hydrogen now starts for the negative plate, but meets the sulphate of copper on the way, detaches the copper, and deposits it upon the negative plate, thus:

$$H_2 + CuSO_4 = H_2SO_4 + Cu.$$

The gravity battery (*Fig.* 39) illustrates the same principle. As the porous cup is likely to become impregnated with copper, especially if much used upon an open circuit, it may be dispensed with and advantage taken of the difference in density of the two fluids employed. The zinc is suspended in a dilute solution of sulphate of zinc, and the copper lies at the bottom of the jar in a saturated solution of sulphate of copper. This is a most serviceable battery for continuous work, and is not liable to get out of order. Other batteries of this type are those known respectively as Grove's and Bunsen's.

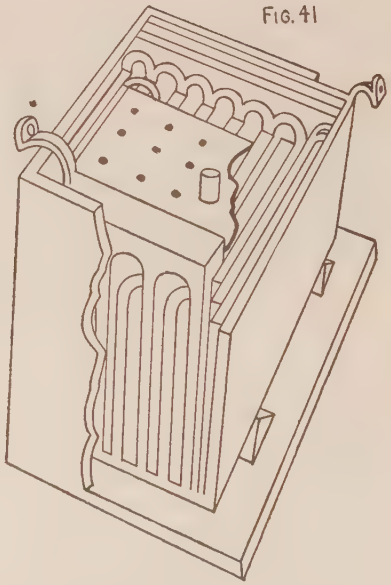
For producing the direct current for use in country districts, where the electric lighting mains are not accessible, it is customary to use from forty to fifty cells of the Leclanché type. A separate group of these cells may be used to excite an induction coil. Bichromate of potassium batteries are occasionally used for the same purpose, but the cleanliness and ease of handling of the sal ammoniac battery are greatly in favor of the latter.

Dry Cells.— These furnish a convenient method of providing an electric current. They represent the Leclanché type of battery. In the usual form (*Fig.* 40) the zinc element is made in the

shape of a canister into which a conglomerate of material — which varies in different makes — is introduced and moistened with the exciting fluid. This is packed around the carbon element in which polarization may be avoided by using binoxide of manganese, and the ends of the canister are sealed to prevent evaporation. Such cells have a long period of usefulness, but will, of course, finally run down, and as they cannot be effectually revived, must be thrown away. Like the Leclanché cell they are adapted for use on open circuits.

Fig. 40.

FIG. 41



Accumulator Cell showing arrangement of plates.

ACCUMULATORS OR SECONDARY BATTERIES.— These are called secondary batteries, because when

run down — unlike primary batteries — they can be renewed by driving an electric current into them. They are also called storage batteries, though there is no storage of electricity, but an accumulation of potential energy ready to manifest itself as electricity.

As ordinarily constructed (*Fig.* 41) an accumulator consists of two or more lead plates immersed in a solution of sulphuric acid and water, having the proportions of one part of the former to five parts of the latter. The acid forms a layer of sulphate of lead upon the surface of the plates. If now a direct current of electricity be passed through such a battery, bubbles of oxygen will appear on the positive plate and bubbles of hydrogen on the negative. This is the now familiar effect of electrolysis, as already described in Chapter II on the physics of the direct current (*Fig.* 9). The nascent oxygen changes the sulphate of lead $Pb(SO_4)_2$ to a peroxide of lead PbO_2, a dark, chocolate-colored substance, thus: $2H_2O + Pb(SO_4)_2 = PbO_2 + 2H_2SO_4$. The nascent hydrogen reduces the sulphate of lead $Pb\ (SO_4)_2$ on the negative plate to a spongy gray substance, or metallic lead, thus: $2H_2 + Pb\ (SO_4)_2 = Pb + 2H_2SO_4$. When the process of charging is complete, the gases escape through the liquid rendering it milky.

If now the charging wires are detached and the poles of the battery are connected by means of a conductor, an electrical current is produced in an opposite direction, and continues until the plates are in their original condition. The accumulator may be recharged and the process repeated indefinitely. The

accumulator reaches its maximum of efficiency when the layer of material upon the plates has acquired a certain depth and porosity.

Secondary batteries supply a powerful current of about two volts per cell. Their capacity is generally expressed in ampere hours, that is, the number of hours in which the battery can be discharged at the rate of one ampere per hour. Thus, if an accumulator has a capacity of twenty-four ampere hours, we may derive from it a current of two amperes for twelve hours, or one ampere for twenty-four hours.

Accumulators may be charged by a primary battery, dynamo, or from the direct current electric lighting mains.

Magneto-machines.— The demand for larger currents than can be furnished by direct current batteries and accumulators has led to the application of principles, already explained in Chapter III, on the physics of the induced current, to the construction of machines capable of delivering currents of great volume and intensity.

We there saw that if a core of soft iron be placed inside of an induction coil connected with a galvanometer and one of the poles of a bar magnet be moved back and forth over the extremity of the core, the needle of the galvanometer was violently agitated, being moved in one direction at the approach of the magnet, and in an opposite direction at its departure, and that if the opposite pole was used, the movements of the needle were exactly reversed. The same results obtain if the magnet is stationary and the coil is moved.

We may, therefore, construct a magneto-electric machine (*Fig.* 42) consisting of a permanent horse-shoe magnet and two helices enclosing soft iron bars, having their wires wound in opposite directions and attached to an armature. The helices and armature are rigidly attached to a shaft which is turned by a crank. When the shaft is turned the armature with

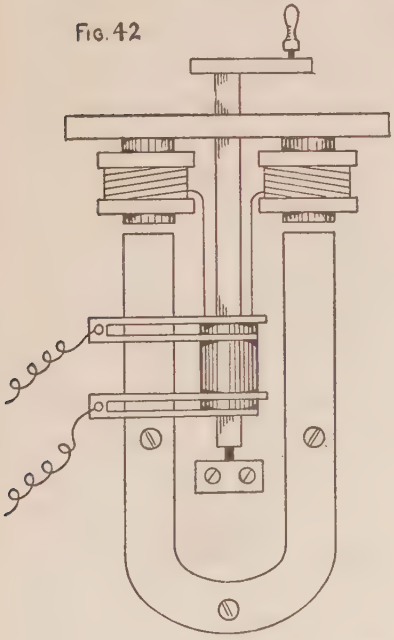


FIG. 42

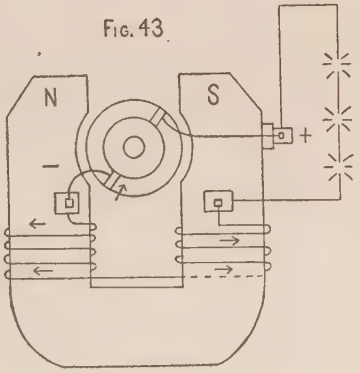


FIG. 43

its helices moves away from the poles and a current of electricity is established in both helices. As the wires in the helices are wound in opposite directions, the currents flow in the same direction and are doubled. During the second quarter revolution the poles approach each other. We should now expect

a reversal of the current in the helices, but the polarity of the soft iron cores changes also, thus preserving the original direction of the current. At the beginning of the third quarter revolution there is a reversal of the current, because the polarity of the cores does not change. It thus appears that at each revolution the current runs in one direction half the time and in the opposite direction the other half. In order, therefore, to secure a constant current, a current reverser or commutator is placed on the shaft and connected with the terminals of the helices by means of brushes.

The commutator is composed of strips of metal insulated from the shaft and from one another, and so arranged that opposite currents are delivered in the same direction. Such a machine produces a continuous current.

Dynamo Machines.— The machine described above serves to explain the principle upon which magneto-electric machines work, but is not generally in use for generation of direct currents. For this purpose the principle of the electro-magnet is employed, as illustrated (*Fig.* 43). Here the currents generated by the rotation of the armature are employed to magnetize the soft-iron horseshoe. This is called the field magnet, and the small quantity of residual magnetism remaining in it serves to set up currents in the armature when it is revolved. These currents passing round the field magnet still further increase its magnetism. The increased magnetism of the field magnet exerts an increased effect upon the

armature, and thus by the reaction of the armature upon the field magnet, the latter becomes fully magnetized. The arrangement above described for reversing the currents by means of commutator segments and sending them in one direction is also here employed.

When the whole current passes first through the field magnet coils and then through the outer circuit, the dynamo is said to be "series wound"; when a portion of the current is in parallel and passes through the field magnet coil, the dynamo is said to be "shunt wound."

Alternating Dynamos.— When the commutator strips or segments are replaced by two insulated metal rings on the shaft, the dynamo delivers an alternating current. In other words, the current is not continuous, but rises and falls with a wavelike motion. When a closed coil or circuit is rotated in a magnetic field, it is traversed by a current which rises to a maximum, then gradually falls away to zero, and is succeeded by a current of opposite sign, which rises to a maximum and falls away to zero. This is called a "cycle," and alternating currents are characterized by the number of cycles which they make in a second. Each cycle is made up of two semi-cycles, one corresponding to the passage of the coil through lines of N magnetism, and the other to its passage through lines of S magnetism. In such machines a permanent magnet is used, or if an electromagnet is employed, the current traversing the field magnet is derived from another source than the armature.

The variations already described may be represented graphically by a curve. (*Fig.* 44.) If a horizontal line be drawn to represent periods of time, and a perpendicular above and below the horizontal line to represent electromotive force, then an electromotive force gradually rising from zero and falling again could be represented by a curved line, and a continuation of the curved line below the horizontal line would indicate the reversal of the sign.

Thus in (*Fig.* 44) the curve A B C rises from zero to its maximum of thirty volts, then falls to zero, and continuing as C D E falls to its maximum of thirty volts negative and returns to zero, the periods of time of the whole cycle being represented by the

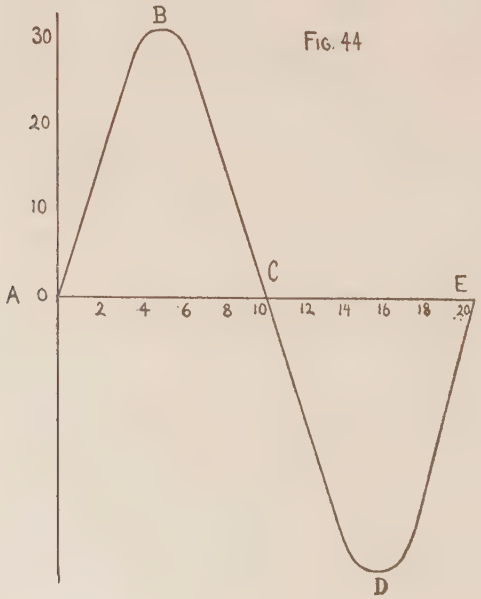


FIG. 44

horizontal line A E. This curve approaches closely to the curve of an alternating system of electric light supply, and is known as a simple periodic curve or a sine curve. Thus the current from an alternating current dynamo is often called a "sinusoidal" current, because its curve approximates in its wave form to a true sine curve.

TRANSFORMERS.—Alternating currents are extensively employed, because of the ease with which

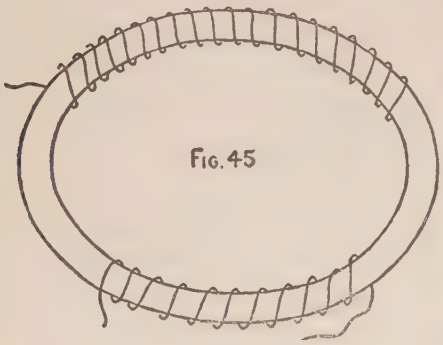


Fig. 46.

their voltage can be changed by means of transformers. In direct currents resistances are interposed to reduce the pressure. These resistances consume the current but do not transform it. The ease with which alternating currents lend themselves to transformation renders these currents commercially very popular and relatively cheap. Thus a current of fifty amperes at one volt may be transformed into a current of one ampere at fifty volts, or one one-thousandth of an ampere at fifty thousand volts with slight losses.

These changes are affected by means of an apparatus called the transformer. This consists of two coils wound like an induction coil or on opposite portions of a soft-iron ring. (*Fig.* 45.) The current is passed into the primary wire from the alternating dynamo, and a current induced in the secondary wire. No interruptions are required as these already exist in the alternating currents. The change in the character of the current induced depends upon the ratio of the number of turns of wire in the two coils. Thus where a large amperage and a small voltage are required, as in electro-cautery lamps, it can readily be perceived how the use of a suitable transformer in connection with an alternating dynamo would produce the desired result.

Figure 46 represents a cut of a transformer to be used in connection with an alternating dynamo for the purpose of heating cautery knives and illuminating diagnostic lamps.

CHAPTER VII

THE UTILIZATION OF ELECTRIC LIGHT MAINS

The demand for large currents of electricity for commercial uses has made the installation of dynamo plants, in communities of any considerable size, a necessity. Such currents, furnished primarily for electric lighting purposes, may be used by the physician:

(1) To take the place of currents generated by direct current batteries for therapeutic purposes;

(2) To supply alternating or sinusoidal currents;

(3) To illuminate diagnostic lamps;

(4) To excite coils for high frequency and X-ray work;

(5) To illuminate incandescent and arc lamps for therapeutic purposes;

(6) To drive motors for the operation of static machines, drills, saws, trephines, etc.;

(7) To heat electro-cauteries; and

(8) To charge secondary or storage batteries.

Let us consider briefly, in order, each of these uses, and, first, the use of commercial currents as a substitute for direct current batteries.

1. Here the first and most important problem is the reduction of pressure. Assuming for convenience of calculation that the direct current furnished is at a pressure of one hundred volts, we readily perceive that this must be reduced in order to be available for therapeutic uses. In order to accomplish this end we may employ lamps placed in series, and thus render the current suitable for therapeutic applications. The carbon filament of incandescent lamps offers a marked resistance to the passage of the electric current. Thus with a one hundred volt current an eight candlepower lamp when hot offers a resistance of 320 ohms; a sixteen candlepower lamp, 160 ohms; a thirty-two candlepower lamp; 80 ohms. By Ohm's law, therefore, $C = \frac{E}{R}$, we may readily ascertain what current is delivered on short circuit. Thus with an eight candlepower lamp the current delivered would be as follows; $C = \frac{100}{320}$ or .31 ampere, or a little over three tenths of an ampere. Similarly we find that a sixteen candlepower lamp would permit about six tenths of an ampere to pass, and a thirty-two candlepower lamp about 1.37 amperes.

Shunt Resistances.— It is preferable, however, to regulate currents by a combination of series and shunt resistances as shown in Figure 47. See also Figure 21, Chapter III, on the physics of the induced current. Here the current from the mains A B passes on the positive side through a switch C, and the shunt coil to the metal traveler E and the galvanometer F to the positive terminal. On the

negative side it passes through the lamp H to the negative terminal. It will thus be seen that in order to reach the patient the current must pass through the resistance coil D and the metal traveler by which the number of coils of wire interposed between the main and the patient is regulated.

Thus upon a 110 volt main, assuming that the lamp consumes ten volts, we shall have a residual

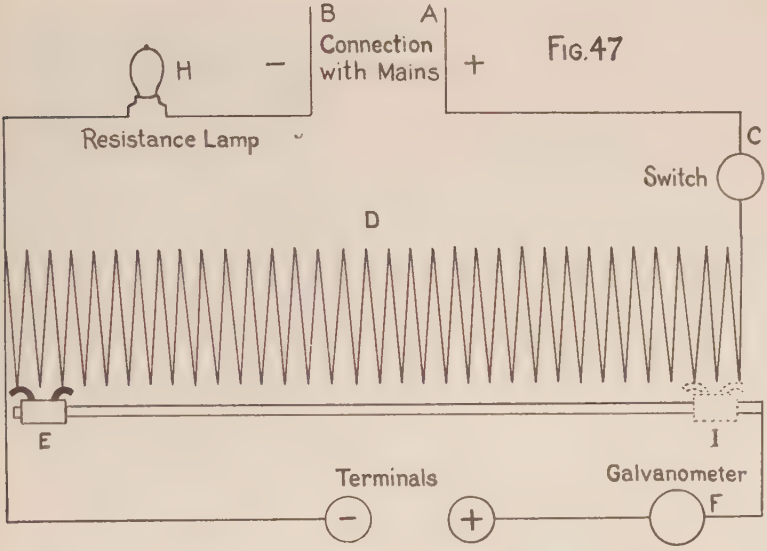


Fig. 47

pressure of one hundred volts for the patient's circuit when the metal traveler is at I, and zero when it is E, with all intermediate voltages between. Assuming that there are five hundred loops in the coil, then a movement from one loop to the next would mean a potential variation of one fifth of one volt and a movement over five loops one volt. This arrange-

ment affords a satisfactory solution of the problem of regulation for small currents.

Regulation of Large Currents.—Here it is customary to pass the current through a series of open coils affixed to the surface of a slate or marble slab (*Fig.* 48). These coils, usually made of thick iron wire, are arranged in series, and wires are led off

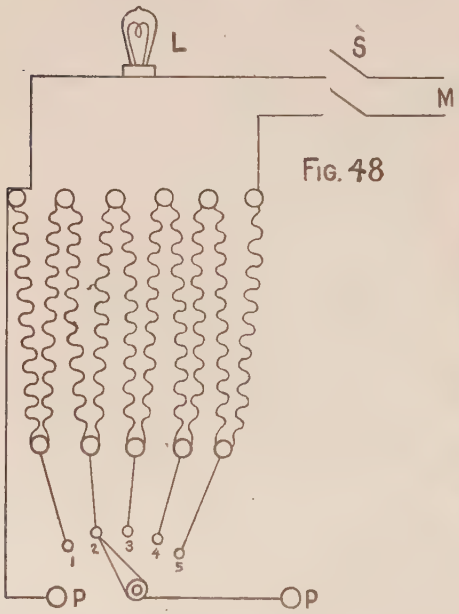


Fig. 48

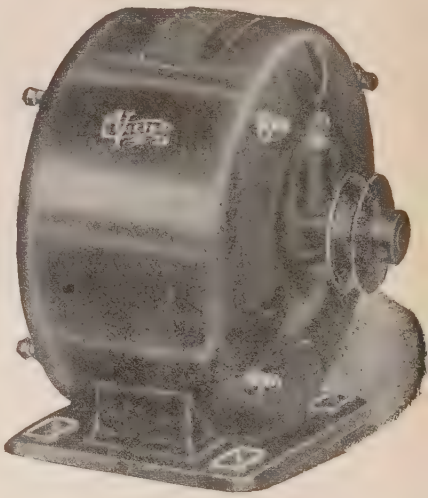


Fig. 49.

at successive points to studs upon the surface of the switchboard, whence the current is carried to the patient through a crank arm. Assuming that there are ten lengths of wire in the spirally coiled wire, that the pressure is 110 volts, and that ten volts are consumed in the resistance lamp L, then the difference of potential between two successive studs would be

one fifth of the total available pressure, or twenty volts. Thus when the crank arm stands on stud one the difference in potential between P and P′ would be one tenth of the total pressure, or ten volts. When the crank arm stands on stud two the difference would be three tenths, or thirty volts; on stud three five tenths, or fifty volts, and so on. It can readily be seen that shunt resistances may consume a large amount of current as, though a small amount may enter the utilization circuit, the subscriber must pay for the current that enters the resistance coil. Thus, if a shunt with a one hundred volt pressure carries twenty amperes, and is connected with the main for one hour, we shall have $20 \times 100 \times 1 = 2000$ watt hours, since a watt hour is the product of the amperage into the voltage for a unit of one hour, or, expressed differently, two kilowatt hours, since a kilowatt equals 1000 watts. The price per kilowatt hour being in Boston twelve cents, the subscriber would therefore pay for this service twenty-four cents.

Shunt Resistances in Electro-Cautery Apparatus. This method of controlling the current is much to be preferred over an arrangement in series. When, for instance, it is desired to use a current of ten amperes from a one hundred volt commercial main, this could be obtained by using a lamp of ten ohms resistance, since $C = \frac{100}{10} =$ ten amperes. But as a current of ten amperes is sufficient to leap across an air gap, it might happen that upon breaking the circuit at the key in the cautery handle, an arc would be established which would destroy the handle, or if

the platinum fused, might send a shower of platinum and copper upon the patient with dangerous consequences. The use of a shunt resistance avoids such a calamity, since the shunt circuit would carry the current in case of destruction of the cautery circuit.

2. Sinusoidal or Alternating Currents for Therapeutic Uses.— These may be obtained by connecting an alternating dynamo, as described in Chapter VI, with the direct current mains (*Fig.* 49). By combination with a transformer described in the same chapter (*Fig.* 46), the voltage may be reduced and the amperage raised for cautery purposes. Such a generator may be used in connection with a wall plate and regulated by means of a shunt resistance.

3. Small Lamps for Diagnostic Purposes.— Here the current from the commercial mains must be reduced by means of resistances. For this purpose an incandescent lamp may be arranged in simple series, or a wire resistance together with an incandescent lamp may be employed.

Assuming a current of one hundred volts with a sixteen candlepower lamp in simple series, since the resistance of a sixteen candlepower lamp is about 160 ohms, we have by Ohm's law $C = \frac{E}{R}$, $C = \frac{100}{160}$ or five eighths or about six tenths of an ampere, which would be sufficient to light a small diagnostic lamp.

Small lamps may be illuminated by portable accumulators or they may be connected with the mains through an alternating dynamo and transformer (*Fig.* 45, *Chap. VI*).

4. Coils for the Production of X-rays and High Frequency Currents.— The principle of the transformer has already been explained in Chapter VI. It was there shown that, by means of a transformer used in connection with an alternating dynamo, the relation of voltage to amperage could be altered to any ratio desired. For electro-cautery purposes the amperage needs to be increased, but for the production of X-rays and high frequency currents the voltage is enormously increased and the amperage correspondingly reduced.

5. Lamps for Therapeutic Applications. (*a*) *Incandescent* lamps connected with the commercial mains furnish heat and light. The value of heat for therapeutic purposes has always been recognized, and contrivances for applying heat to the body have been used from time immemorial. Radiant light and heat, as furnished by the incandescent lamp (*Fig.* 50) are of undoubted value, stimulating the sweat glands and favoring the excretion of toxic materials through the skin. The important relation which light bears to vegetable growth makes it probable that the luminous rays of the spectrum

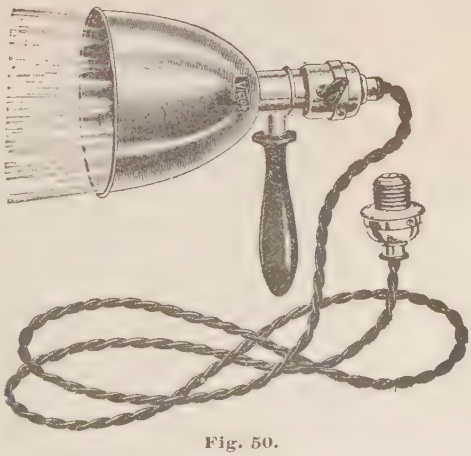


Fig. 50.

share with the thermic rays in the remarkable results which have followed the use of these lamps. (*b*) *Arc lights.* These lamps supply the violet and ultra-violet portion of the spectrum as well as heat and light rays (*Fig.* 51). Incandescent lamps yield the chemical rays of the spectrum in relatively small measure. Finsen recognized the importance of the actinic radiations in his use of the sun's rays and the arc light. To his labors the profession of medicine

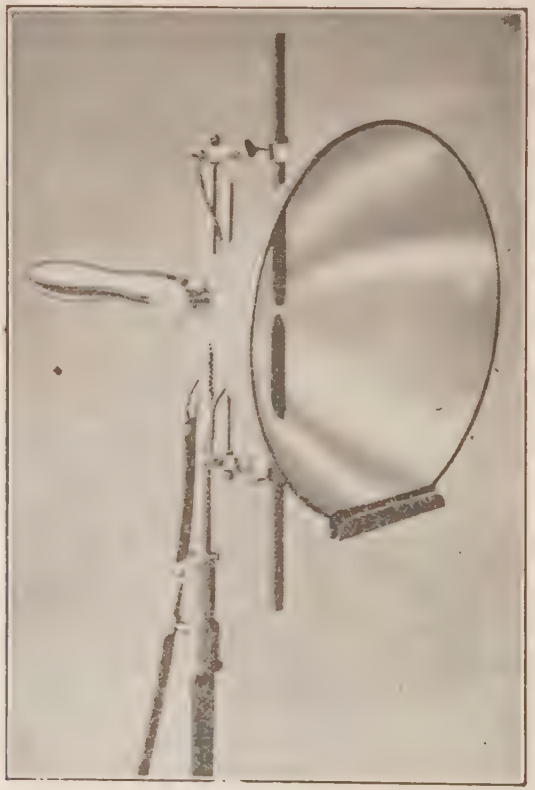


Fig. 51.

owes the discovery of the cure of lupus through the concentration of the sun's rays or the radiations from an arc lamp upon the affected area. He employed lamps consuming eighty amperes of current which threw their light through tubes terminating in quartz lenses. These lenses focused the light and concentrated it upon the area to be treated. They were kept cool by running water and pressed upon the diseased area in order to render the tissue free from blood, which tends to resist the passage of the chemical ray.

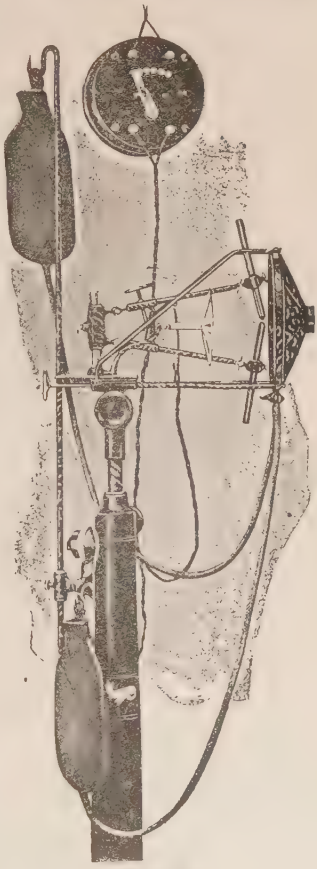


Fig. 52.

The great size and cost of such an installation, as is described above, have rendered it desirable to employ smaller lamps, consuming less current, but yielding results equally satisfactory. The limits assigned to these chapters do not permit an exhaustive description of these lamps. It is, however, interesting to note the evolution of arc lights from the ponderous and expensive apparatus of Finsen to the simpler but

very effective lights which have supplanted those employed by the Danish pioneer.

Lortet-Genoud Lamp. One of the earliest of these lamps is that known as the Lortet-Genoud lamp, which has served as a model for other lamps bearing a different name. This is a portable lamp and has both a cooling shield and a compressor.

Condenser Spark-Gap Lamp. In another variety of lamp advantage is taken of the fact that condenser spark discharges are especially rich in actinic rays. This is known as St. Bartholomew's lamp and has proved of great service in the treatment of lupus.

Uviol Lamp. This lamp adapts the Cooper-Hewitt lamp to therapeutic uses. The latter consists of a glass tube exhausted of air and containing mercury or mercury vapor. When traversed by an electric current the tube glows with a brilliant light, which is very rich in the actinic portion of the spectrum, but deficient in calorific rays. As, however, ordinary glass is impervious to the ultra violet rays of the spectrum, a variety of glass, recently manufactured, is employed, which is said to be pervious to these rays. The uviol lamp consists of a tube of this special glass eight to thirty millimeters in diameter and twenty to thirty centimeters in length. It furnishes a light exceedingly rich in the violet and ultra violet portions of the spectrum. There are numerous lamps of American manufacture which follow more or less closely the design of the Lortet-Genoud lamp above described. Among these are the solar lamp (*Fig.* 51), and the Victor Finsen lamp (*Fig.* 52), the latter

in particular reproducing the lines of its original with much fidelity. The solar lamp is designed to occupy the field hitherto cultivated by the incandescent, furnishing not only light and heat but the highly important chemical rays of the spectrum.

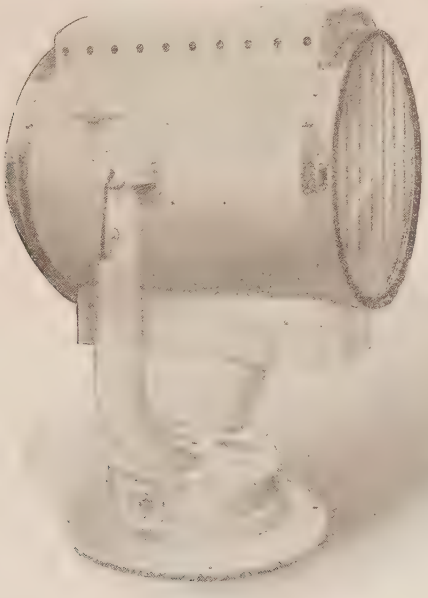
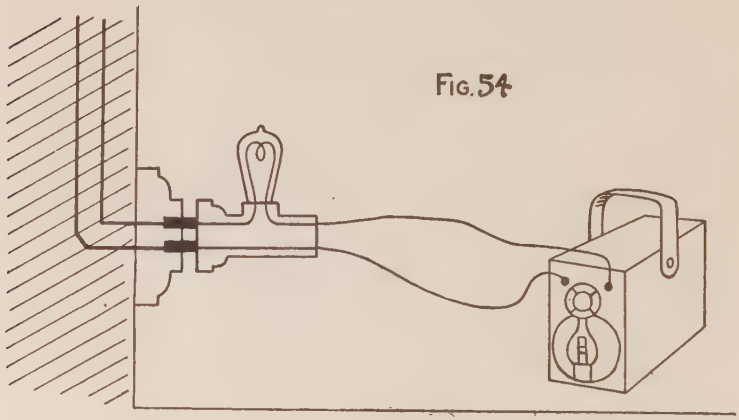


Fig. 53.

For this purpose the marine search light as manufactured by the Carlisle & Finch Co., of Cincinnati, Ohio (*Fig.* 53), is admirably adapted, furnishing an enormous volume of light, and lending itself readily to adjustment and manipulation. For therapeutic purposes a lamp using twenty-five amperes and illuminating objects at a distance of a mile and a quarter may be successfully employed.

6. To Furnish Power for Static Machines, Drills, etc.— This is an obvious application of the current from the commercial mains and needs no detailed description.

7. To Heat Electro-Cauteries.— This may be done in several ways. (*a*) An accumulator or secondary battery may be charged from the direct current mains through an incandescent lamp and used to heat a cautery (*Fig.* 54). (*b*) The pressure of the commercial mains may be reduced:



First, by using a motor dynamo with two distinct windings in the armature, one to receive a current, say, of 110 volts from the commercial mains, and the other to give off a larger current, say, of ten amperes at eleven volts pressure, or,

Secondly, by using a motor dynamo to turn an alternating dynamo which is combined with a transformer (*Fig.* 46).

8. To Charge Accumulators or Secondary Batteries.— Storage batteries are useful for many purposes. They may be charged from the commercial mains and carried to the patient's house for treatment, or they may be used for lamp or cautery purposes even when the mains are accessible, because they supply a reduced pressure without requiring additional apparatus for increasing resistance.

Conversion of Alternating Currents into Direct Currents.— In many communities the alternating current is the only current that is furnished by the commercial mains. This current lends itself readily to transformations, and can thus be easily distributed as needed upon commercial circuits.

Such currents are, however, not always suitable for medical purposes and it therefore becomes necessary to convert them into direct currents. This may be done in a variety of ways.

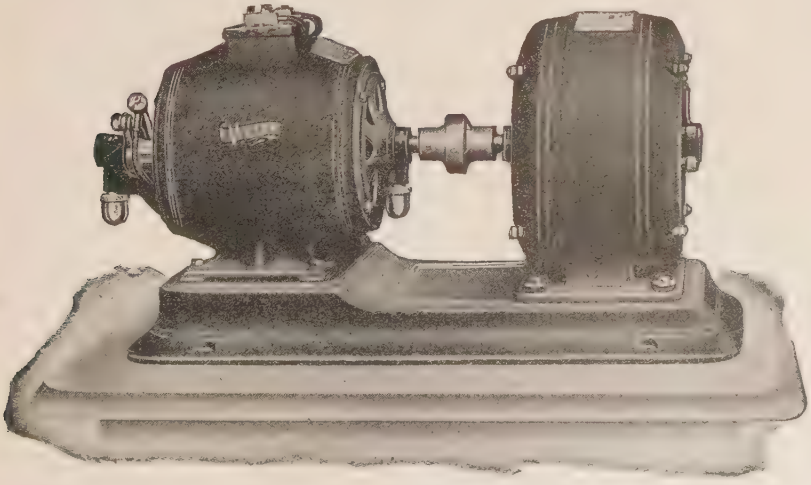


Fig. 55.

(*a*) An alternating motor may be used to drive a direct current dynamo. Figure 55 represents an alternating motor coupled to a direct current generator.

(*b*) A mechanical rectifier may be employed. This is a contrivance which by making contact at the proper moment closes the circuit and transmits impulses flowing only in one direction, while arresting those that flow in the opposite direction. This gives a series of impulses flowing in the same direction. Batten's rectifier illustrates this principle.

(*c*) Electrolytic rectifier. This depends for its efficiency upon the peculiar behavior of aluminium when placed in the circuit of an alternating current. It has long been known that aluminium, when acting as the anode of an electrolytic cell, offers a high resistance to the current, but when acting as the kathode offers no such resistance. If, therefore, an electrolytic cell has aluminium for one pole and a metal or carbon for another, it will permit the passage of an alternating current through it in one direction, and oppose its passage in another.

Such a cell may consist of a plate or rod of aluminium immersed in a jar of ammonium phosphate solution for one pole and an iron plate for the other. This may be connected by means of a conductor and a simple lamp resistance with the alternating mains and used to charge an accumulator, provided that the direction of the flow from iron to aluminium is toward the positive pole of the accumulator.

Nodon's Valve.— The disposition of cells in an electrolytic rectifier may be illustrated by a diagram which involves the principle of the Wheatstone bridge. (*Fig.* 56.) Four cells are arranged in circuit and the direction from iron to aluminium, that is from anode to kathode, is indicated by the arrows. The alternating current enters at A B, but it cannot pass in either direction because it is opposed

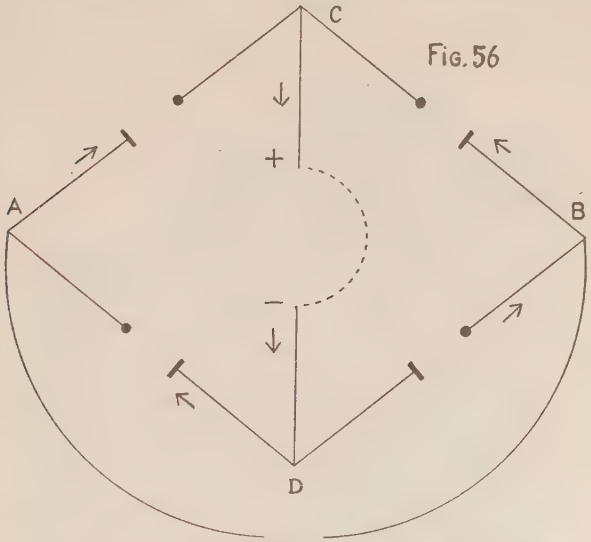


Fig. 56

by one or the other of the aluminium cells. But if C and D are connected, as indicated by the dotted line, the current will pass through A C D to B, and when the current is reversed and B is positive it will pass through B C D to A. The aluminium cell as thus arranged may be used to drive direct current motors, charge accumulators, and excite Rhumkorff coils. The current derived from a rectifier is uni-

directional but pulsatory. Though not a steady current it may be used when the direct current is required, as a cheap but somewhat unsatisfactory substitute for the method described under (*a*).

In the Nodon's valve, as above described, the electrolyte is a solution of ammonium phosphate, and the aluminium poles are probably alloyed with zinc.

Therapeutics of the Alternating Current. — The alternating current supplies, as already de-

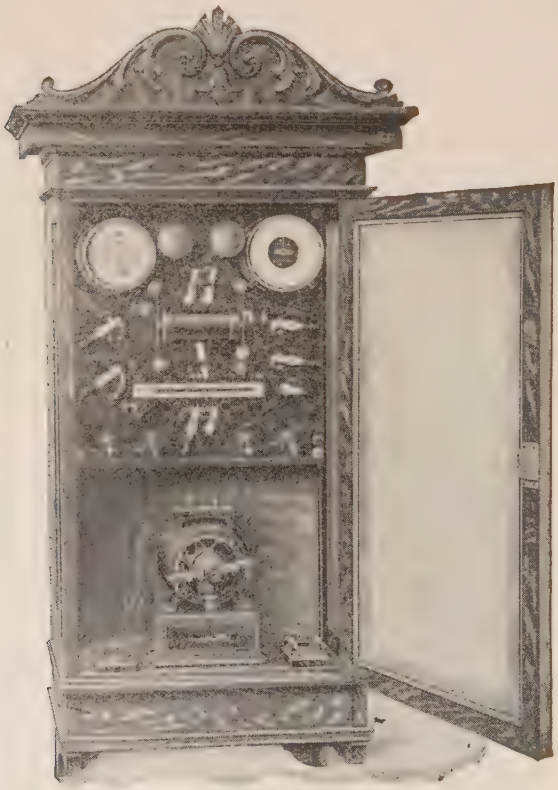


Fig. 57

scribed in Chapter VI, the so-called sinusoidal current. The curves from alternating generators are not similar to sine curves but they are near enough to them to be satisfactory for medical purposes.

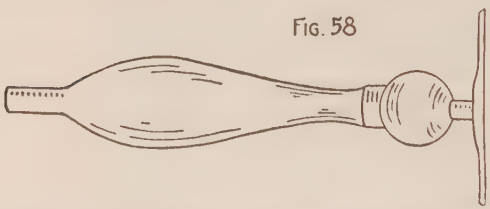
Figure 57 represents a wall plate made by the Victor Electric Company. Such an arrangement connects with the commercial mains and illustrates many of the principles explained in this chapter. It furnishes direct, interrupted, induced, sinusoidal, cautery, and diagnostic lamp currents with milliamperemeter, volt regulator, direct current interrupter, and pole changer.

CHAPTER VIII

ELECTRODES. RHUMKORFF COILS. INTERRUPTERS

If an ordinary disk electrode (*Fig.* 58), consisting of an insulating handle provided with a socket to receive the tip of a stranded copper wire conductor at one end and a disk of brass or copper at the other, be applied to the skin, a similar electrode being applied to another part of the body, when the circuit is closed a disagreeable and painful sensation is experienced.

Fig. 58



On the other hand, if sponge electrodes are applied to the skin in a similar manner, it is observed

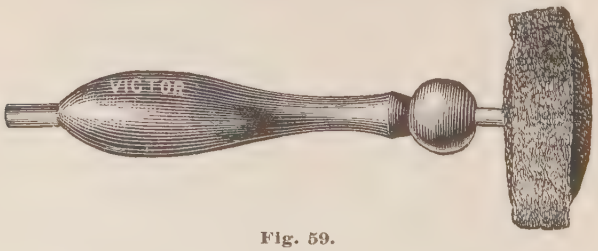


Fig. 59.

that the same amount of current can be passed into the tissues with little or no sensation, especially if

the sponges be first moistened. (*Fig.* 59.) It is thus evident that unmoistened skin opposes a marked resistance to the passage of the electric current, and that the resistance is reduced and pain largely inhibited by the use of an electrode that moistens the surface of the body, and makes close apposition with the area under treatment.

If now two sponge electrodes are moistened with a saturated solution of sodium chloride in water, and similarly applied, it is found that with the same pressure a higher milliamperage is recorded. The conducting power of a saturated solution of sodium chloride in water is three thousand times as great as that of water alone. The use of salt, however, to promote the conductivity of the current is attended with two disadvantages: namely, first, it oxidizes metallic electrodes; and, secondly, the electrolytic decomposition of sodium chloride in solution with the appearance of chlorine gas at the positive pole and sodium at the negative is painful at the points of application of the electrodes.

In like manner, if the electrodes are enlarged it is found, that, with the pressure remaining the same, the milliamperage is increased in proportion as the surface of the electrode is increased.*

If, again, we provide ourselves with two large moistened electrodes and pass a current of ten

*Leduc has, however, questioned the soundness of these propositions. See his speech at the Fourth International Congress for electrology and radiology at Amsterdam, where he denies the influence of moisture in altering the resistance of the body, and declares that the amount of current transmitted is proportional to the periphery of the electrode, and not to its surface area.

milliamperes through the body, we shall, perhaps, note but little pain. If we substitute a smaller electrode for the active pole we shall note an increase of pain, and if the electrode be much reduced, the pain may be unbearable. It thus appears that as the area of the electrode is decreased and the density of the current is increased, pain is increased.

From these experiments we may infer:

That an electrode designed for ordinary therapeutic application to the skin should be made of material that easily adapts itself to inequalities of surface;

That it should be moistened with a fluid that readily carries the current, and

That it should be as large as possible relatively to the surface over which it is placed.

When it is impossible to use large electrodes at both poles, the so-called indifferent electrode may be large, and the active electrode adapted to the work required.

Formerly sponges fastened to metal disks were generally used for therapeutic applications to the skin. Sponges, however, are not sanitary, and should be abandoned. When small metal disks are used they may be covered with absorbent cotton applied to the surface and wrapped around the shank. This is then moistened with soap and thrown away after use. Figure 60 represents the method of applying cotton to the disk.

Larger electrodes may be made after the pattern suggested by Massey. A coil of No. 20 soft brass

wire is sewed upon a circular piece of cotton cloth, the concentric coils being about one half inch apart. Six or eight layers of absorbent cotton are then piled on the wired side, and covered with a piece of cotton

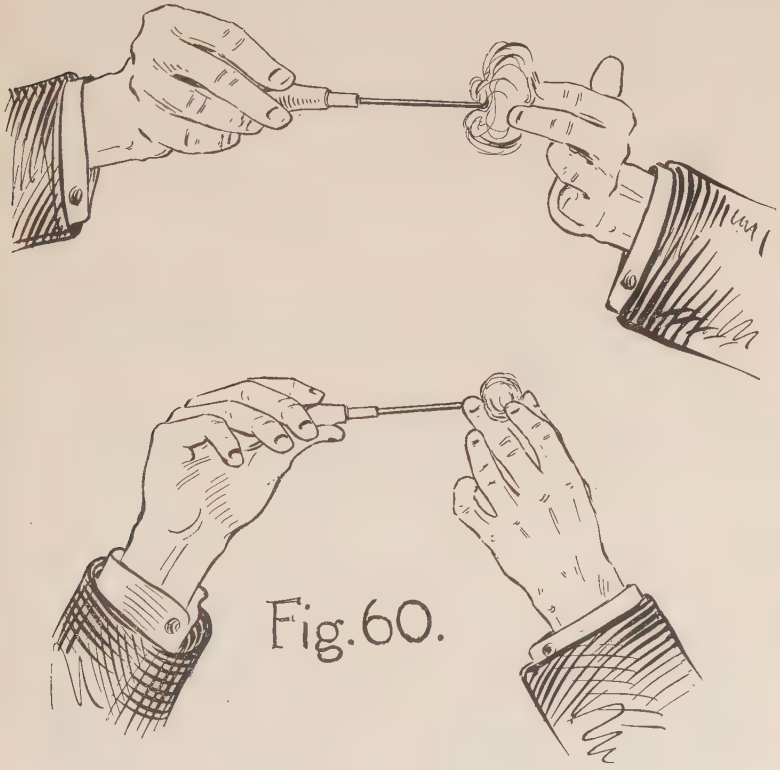


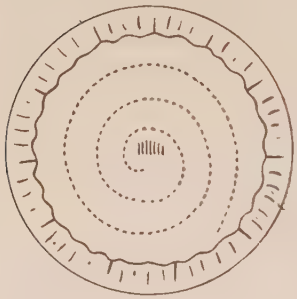
Fig. 60.

cloth which is sewed to the edge of the back of the pad. These pads may be made in any size desired, and should be sterilized after use. (*Fig.* 61.)

The electrodes made after the pattern of Morse

are admirable in design. They consist of a back of rubber cloth covering a piece of finely meshed wire, to which a socket to receive the cord tip is soldered. Beneath this is a layer of asbestos, which is held in place by a piece of coarse cloth stitched to the edges of the rubber back. These may be readily made by nurses, and should be frequently sterilized.

Fig. 61



In still another type of easily extemporized electrodes a layer of spongio-piline is fastened to a piece of block tin to which a socket for the reception of a cord tip is soldered. (*Fig.* 62.) An excellent type of electrode is represented in Figure 63, named after its inventor, Dr. Hubbell's aseptic pad electrode. It consists of a disk A, over which the material employed is smoothly spread. This is then stretched and firmly held in place by the ring C. The handle

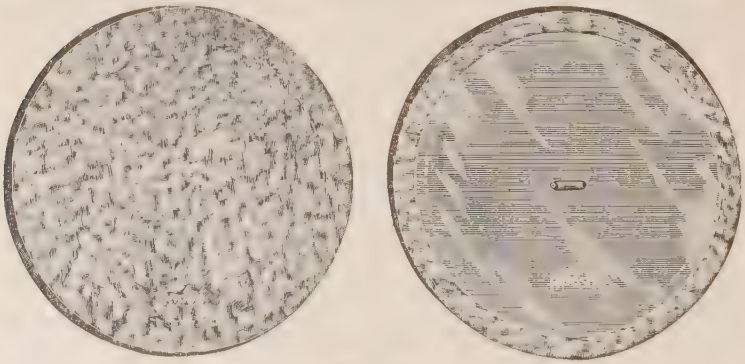


Fig. 62.

is next clamped on the back of the pad, as in D. The cotton or other material employed is thrown away after each treatment.

Rhumkorff's Coil.— In Chapter III, on the physics of the induced current, a brief reference was made to the Rhumkorff coil, which adds to the efficiency of an ordinary induction coil by the use of a condenser. It now becomes necessary, in view of the extensive use of these coils in X-ray and high frequency work, to consider them somewhat more in detail.

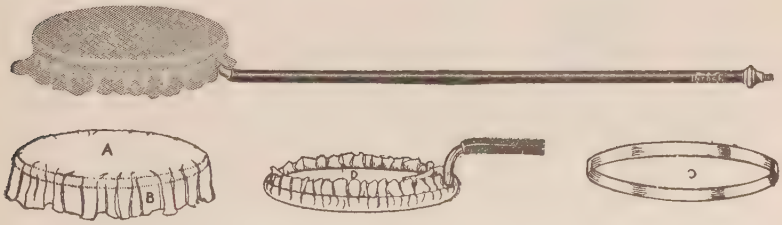


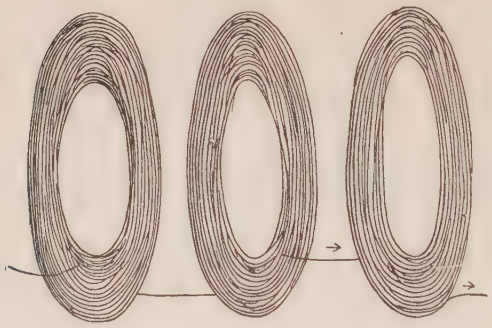
Fig. 63.

Rhumkorff coils are classified according to the length of the spark which they are capable of giving between the prime conductors, as, for example, a ten-inch, twelve-inch, or eighteen-inch coil. The primary winding consists of two or three layers of thick copper wire to enable it to carry heavy currents without heating. A switch arrangement is provided to connect its layers in shunt or series, so as to vary the self-induction to suit the pressure of the source from which the current is derived. Instead of a solid bar of iron, a finely laminated core is used in order to avoid focular or eddy currents which heat

the core, dissipate energy, and tend to retard the sudden demagnetization upon which the coil's efficiency largely depends.

The primary coil is enclosed in a thick vulcanite tube upon which the secondary coil is wound. The diameter of the wire employed in the secondary is much smaller, and the length enormously greater, reaching in some instances as high as ninety or one hundred miles. In smaller coils the secondary wire is wound in layers, in larger coils it is wound in sections, as shown in Figure 64. These may number as many as seven or eight hundred, and are separated from one another by disks of ebonite or paraffin paper. In some coils this number is still further increased.

Fig. 64



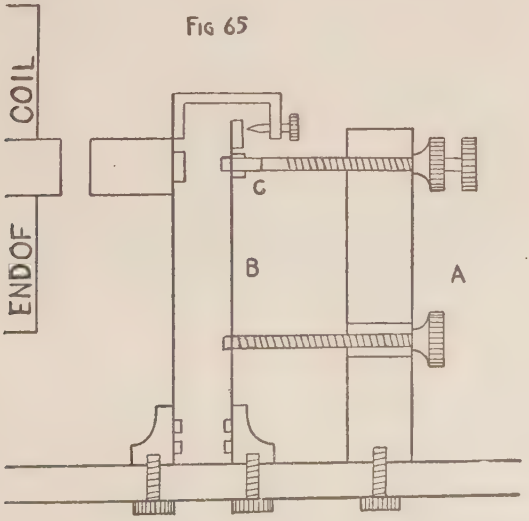
As explained in Figure 20, Chapter III, on the physics of the induced current, a Rhumkorff coil is provided with a condenser, consisting of alternate sheets of tin foil, separated by paraffin paper, and so connected with the primary winding that at the break of the current the extra current may pass into the condenser instead of leaping across the gap of the interrupter, heating it and retarding the decay of the

current, and at the make of the current pass back into the primary coil, and by its reverse direction demagnetize the core and promote rapidity of action. The condenser may be arranged so that the whole or a part may be used.

INTERRUPTERS.— I. *Vibrating Hammer.* The current may be interrupted by a contact breaker, as described in Chapter III, on the physics of the induced current. This has been improved by the use of a tension screw, by which the hammer is made to resist the pull of the core. (*Fig.* 65.)

By increasing the tension of the spring, the full magnetizing effect of the core is secured, and the greatest length of spark obtained. When, however, the tension of the spring is very high the platinum points may stick together, preventing the action of the

FIG 65



A, head of tension screw; B, spring; C, platinum contacts.

secondary coil, and exposing the primary to serious damage. On large coils the vibrating hammer type of interrupter is not satisfactory; first, because the platinum points are likely to stick, and secondly,

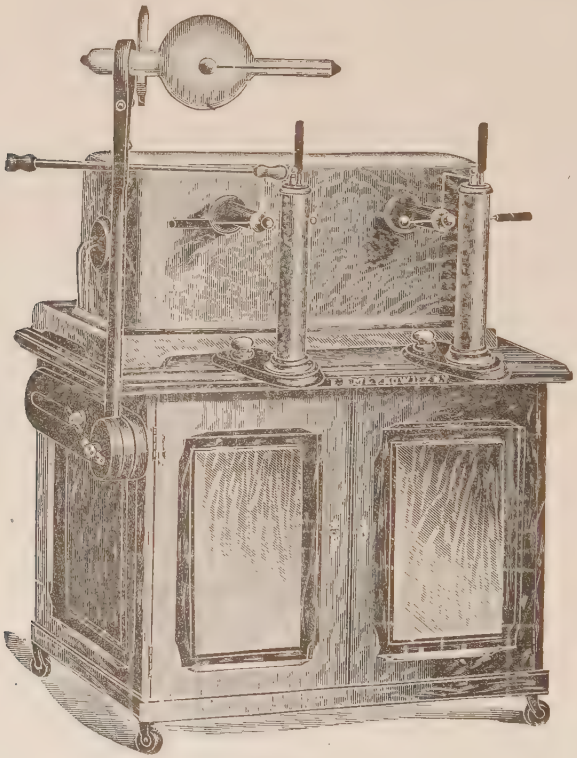


Fig. 66.

because the rapidity of the interruptions of which it is capable is not great enough to secure the highest efficiency of the coil. Therefore it is necessary where coils capable of using large currents are employed to

use interrupters of greater rapidity and uniformity of action.

Figure 66 represents an induction coil with cabinet for the convenient storage of an interrupter, which is manufactured by the E. B. Meyrowitz Co. In coils in which current interrupters are very rapid, condensers are not required.

II. Mechanical Interrupter.— The first and oldest type used as a substitute for the hammer vibrator is the mechanical interrupter. Of this type there are many varieties. The earliest form consists of an apparatus in which contacts are made and broken by a rod dipping in mercury, the movement being effected by a motor whose speed can be varied. This arrangement works well for ordinary speeds, but where the speeds are increased, the mercury is displaced and the interruptions become irregular. An improved form of a mercury interrupter substitutes a rotary interrupter for the "dipper" break. Where mercury is used it is covered with a layer of alcohol or paraffin oil to quench the sparks. Of these types there are several modifications in use, among which may be mentioned the turbine jet interrupter. Here a continuous stream of mercury is propelled by a centrifugal pump. The mercury strikes periodically on contacts and completes the circuit. Many modifications of this type are in use, whose consideration must be omitted for want of space.

III. Electrolytic Interrupters.— (*a*) *The Wehnelt Interrupter.* This device consists of a jar

of dilute sulphuric acid (*Fig.* 67) in which are immersed a lead plate constituting the kathode, and a platinum wire enclosed in an isulating porcelain sheath, which acts as the anode. The extremity of the platinum wire extends beyond the porcelain insulation. A small opening in the porcelain sheath

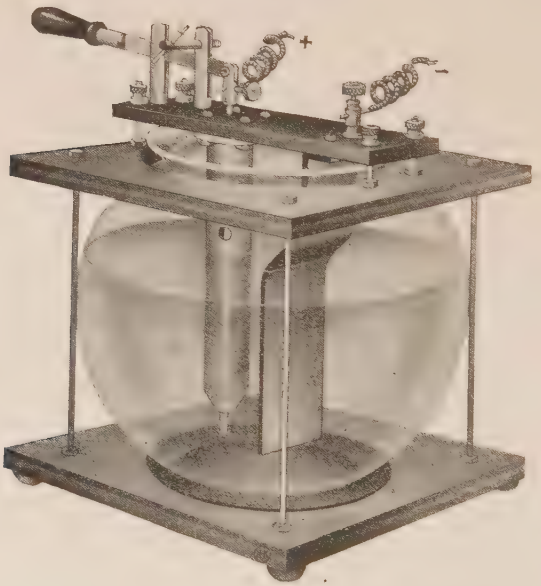


Fig. 67.

permits the escape of fluids which rise above the surface of the electrolyte.

When this apparatus is placed in simple series with a coil, and the circuit closed, hydrogen bubbles and steam are formed at the anode, which act as an insulating envelope. The passage of the spark

destroys the bubbles, which are immediately reformed and again immediately dissipated. This process continues until the electrolyte becomes hot, when the action stops. The premature heating may be controlled by using a large quantity of fluid in the jar. The Wehnelt interrupter permits an adjustment of the platinum anode by which a greater or less surface may be exposed. By regulation of the exposed surface of the anode, the voltage of supply, and the self-induction of the primary coil, excellent results may be obtained from this type of interrupter, and the number of sparks may vary from ten to one thousand per second. The interrupter shown in Figure 67 is used in connection with the GROSSE FLAMME Coil manufactured by the Kelley, Koett Co.

(*b*) *The Caldwell Interrupter.* This consists of

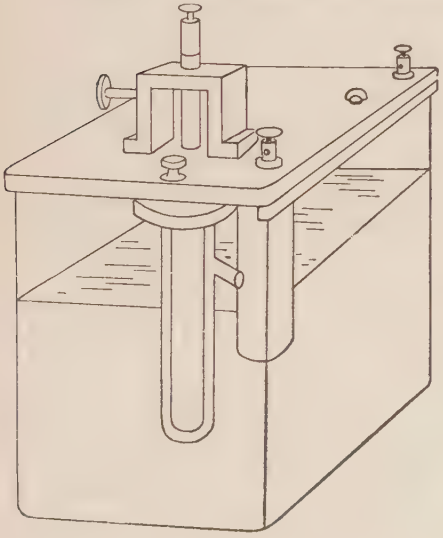


Fig. 68.

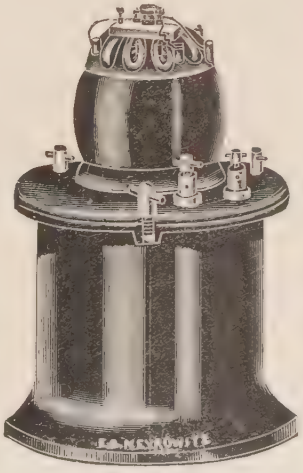


Fig. 69.

a jar (*Fig.* 68) containing dilute sulphuric acid in which are immersed two lead plates, one serving as anode and the other as kathode. One of the plates is enclosed in a glass or porcelain covering, which contains a minute opening. Through this opening the liquid freely circulates. When the current is passed through the jar by means of conductors attached to binding posts, bubbles of steam are formed and quickly destroyed in the opening in the porcelain sheath. Devices are furnished for regulating the size of the hole. The interruptions in this type of interrupter are exceedingly rapid, and produce marked modifications in the appearance of the sparks, which may vary from a shower to sinuous arcs of pale, yellowish-green flames.

Operation of Rhumkorff Coils by the Direct Commercial Mains.— This may be accomplished in various ways.

(*a*) Storage batteries may be charged from the commercial mains, and used to operate coils by means of a hammer interrupter. As such batteries are portable, they can be carried to places where commercial mains are not available, and employed for this purpose.

(*b*) The direct current may be used directly in connection with a shunt resistance. Here a mercury jet or electrolytic interrupter may be used.

(*c*) Instead of a shunt resistance, a series resistance may be used in the primary current, together with a mercury jet interrupter.

(*d*) For high pressures a motor dynamo may

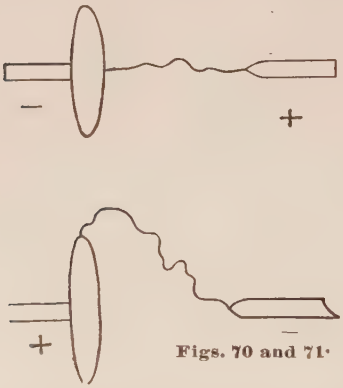
be used generating from sixty to one hundred volts. By introducing a series resistance in circuit with the field magnet windings, the pressure can be made to vary so as to suit either a mercury jet or Wehnelt interrupter.

Operation of Rhumkorff Coils by the Alternating Current Mains.— This is a more difficult problem. If, however, the movement of the interrupter can be made to keep time with the periodicity of the current, the result may be achieved. This would require in a sixty cycle alternating current that the interruption should keep step with the alternation of the current, and occur sixty times in each second. This may be accomplished by means of a mechanical rectifier. Such a rectifier may consist of a steel rod placed on a pivot and turning in the field of an electro-magnet. This rod at one end is successively attracted to each pole of the magnet as its polarity changes, and at its other end, in its excursions, makes contact with each of two studs and thus closes the circuit of utilization. The contacts may be arranged to take place at the crests of the alternating wave currents. Instead of the type of rectifier just described, the aluminium rectifier, described in Chapter VII, may be employed.

Figure 69 represents a mercury interrupter which is used in connection with a synchronous motor. Here the alternations of the motor are synchronized with the interruptions of the current and by an adjusting device the highest voltages in each alternation may be obtained. These methods, however, of which

several more might be mentioned, are efforts to synchronize the alternations of the current with the action of the interrupter, or to convert the current into one which is direct or pulsatory. The natural solution of the problem of utilizing an alternating current is to excite step-up transformers (*Fig.* 45, *Chap.* VI), capable of supplying high voltages. These will be considered in a later chapter.

Spark Discharge.— Upon separating the terminals of a Rhumkorff coil, a thick yellow flame is observed leaping across the gap, which is sufficiently hot to ignite paper. When the terminals are farther separated, the flame becomes sinuous and curves upwards from the convection of heat currents. When still farther separated, zigzag sparks dart across the gap, to be followed by a violet brush discharge with a wider separation of the terminals. To obtain the largest sparks the discharge should occur between a disk and a ball; the ball constituting the anode of the coil. Should the current be reversed the spark will issue from the periphery of the disk. This constitutes an easy method of determining the polarity of the coil. (*Figs.* 70 and 71.)



Figs. 70 and 71.

Effect of Different Potentials upon the Length of the Spark.— Much labor has been spent upon the problem of determining the difference of potential from the lengths of the spark. Results obtained from different observers vary greatly. As indicated above, the length of the spark varies with the shape of the terminals, and it is not always easy to determine when the spark changes from a brush to a spark. Fleming estimates that at distances not exceeding five or six centimeters the voltage required to produce a spark between metal balls is not far from three thousand volts per millimeter, or one hundred and eighty thousand volts for a spark measuring six centimeters, or seventy-five thousand per inch. Other estimates are as low as thirty thousand volts per inch.

CHAPTER IX

PHYSIOLOGICAL EFFECTS OF DIRECT, INDUCED, AND SINUSOIDAL CURRENTS. METHODS OF APPLICATION

In Chapters IV and V, on the physiological effects of direct and induced currents, it was shown that the characteristic effect of the former is to produce chemical change in the tissues; of the latter to produce stimulation. It remains for us to indicate in a general way the conditions to which these currents are applicable, and the best methods of applying them.

Polar Effects. Electrolytic Action of the Direct Current.— The electrolytic action of the direct current is utilized:

(1) In the removal of superfluous hair, moles, and warts;

(2) In the destruction of naevi, port-wine marks, etc.;

(3) In the coagulation of blood in aneurisms;

(4) In the destruction of strictures of the urethra, lachrymal canals, etc.;

(5) In the destruction of hemorrhoids, external and internal;

(6) In the destruction of uterine fibromata, according to the method of Apostoli;

(7) In the destruction of cancerous tissue by

zinc-mercury phoresis, according to the method of Massey; and

(8) For the introduction of medicaments into the tissues by phoresis. The more particular consideration of these varied and important applications must be deferred to later chapters.

It is evident that in the above enumerated applications of the direct current the effect aimed at is principally a local one. This necessitates the use of an electrode upon the active pole especially adapted to the purpose in view, and usually, from its size and composition, capable of carrying a current of considerable density.

Where, however, the conditions to be effected are of a general or constitutional nature, that is to say in the interpolar regions, there is little difference between the electrodes employed, except, perhaps, as to size.

Interpolar Effects. Generalized Action of the Direct Current.— *Central galvanization.* This is a method of applying the direct current to nerve centers introduced by Doctors Beard and Rockwell, for the purpose of general electrization. It consists in placing the negative pole at the epigastrium, while the positive pole is applied to certain parts of the head,— chiefly the vertex and forehead,— to the sympathetic and pneumogastric in the neck, and down the whole length of the spine from the first to the last vertebra. Such applications are useful in neurasthenia, insomnia, hysteria, and other conditions of a similar nature.

Influence of the Direct Current upon the Muscles.— Experiments have been made tending to show that the passage of a direct current through a fatigued muscle refreshes and revives it. In several remarkable cases, reported by Dr. G. V. Poore, of London, it was shown that after a heavy weight had been supported at arm's length for seventy seconds, with production of pain and fatigue, the application of the direct current relieved both, and enabled the subject of the experiment to sustain the weight for an additional five minutes without difficulty and exhaustion.

Further experiment by the same investigator proved that not only the endurance, but the strength of the muscular effort could be increased by the use of the direct current. Having squeezed a dynamometer eight times with an average pressure of forty-eight and a half pounds, the subject of the experiment, with the aid of a light direct current, exerted in eight trials an average pressure of fifty-nine and a half pounds.

These results were confirmed by Capriati,* in 1899, who employed scientific methods of measurement. Having applied a direct current of from ten to fifteen milliamperes along the spine, he found that there was an increase of muscular power which persisted for one or more days.

Effect of the Direct Current upon Strychnine Poisoning.— It was demonstrated by Charpentier and Guilloz that the passage of a direct current

*Archives d'Électricité Médicale.

through guinea pigs and frogs arrests the effects of strychnia poisoning. While the current flows there is quiescence, succeeded by characteristic tetanic spasms when the current is stopped. Death was averted by prolonged electrical applications.

Stimulating Effect of the Interrupted, Direct, or Induced Currents. — D'Arsonval has proved that variable currents, by means of muscular contractions, increase tissue oxidation and quicken metabolism. These results may readily be inferred as a consequence of muscular activity.

Dr. Beard, in "Medical and Surgical Uses of Electricity," records the results of general faradization upon the growth of young dogs. They were treated daily with an induced current for a period of four weeks. At the expiration of that time they had gained in weight faster than had two other dogs, which had been untreated and used as controls.

A very interesting series of experiments upon the hamstring muscles of young rabbits, conducted by Debedat, and recorded in the "Archives d'Électricité Médicale," for February and March, 1904, led to the conclusion that in order to promote the growth of muscle the current should be interrupted, and that these interruptions should occur at regular intervals, at the rate of about thirty per minute, and that prolonged tetanization was hurtful.

Similar experiments upon human muscles, with the combined direct and induced current, interrupted thirty times per minute, showed after two months' treatment marked increase in the size of the muscles treated.

General Faradization.— This method described by Doctors Beard and Rockwell consists in placing a plate attached to one terminal of a faradic coil under the feet or gluteal region, and moving a moistened electrode attached to the other terminal over the body giving two or three minutes each to the head, neck, back, abdomen, and extremities in order.

Galvano-Faradization.— A combination of direct and induced currents may be obtained by joining the negative pole of the direct current battery with the positive pole of an induction coil. The combined current possesses the advantage of each of its components, and is well adapted for use in cases of defective or perverted nutrition, including anemia, chlorosis, neurasthenia, rickets, gout, myalgia, arthritis, etc.

Physiological Effects of Sinusoidal Currents.— Having analyzed the effects produced by direct and induced currents, we are prepared to discover what effects, if any, are peculiar to sinusoidal currents. In the first place it must be evident that the chemical effects which are so characteristic of the direct current must be wanting in sinusoidal currents. Electrolytic action is a property of continuous currents, and is manifested but slightly in interrupted or variable currents. If, then, we eliminate electrolytic action, it must be evident that the peculiar sensation due to chemical decomposition in the tissues will be missing in alternating currents, and the disagreeable sensory effects which originate from this cause will therefore not be observed.

If now we turn our attention for a moment to induced currents, we shall note that an element in the disagreeable sensory effect produced by these currents springs from the sudden interruption of the current. In an alternating current the change of potential (*Fig.* 44) even when rapid is never abrupt. Compare the curves as shown in Figures 31 and 32, Chapter V, on the physiology of the induced current.

Alternating currents are therefore wanting in the disagreeable sensory effects due to chemical action which are characteristic of direct currents, and the irritating sensory disturbance due to the abrupt change of potential which is characteristic of induced currents. The peculiar property, therefore, of muscular stimulation which belongs to induced currents remains, without the disagreeable sensory effects characteristic of such currents.

In Chapter V, on the physiology of the induced current it was shown, by a study of curves (*Fig.* 33), that the interruptions of the current, as produced by a vibrating hammer, are to an extent irregular and uncertain, so that the physiological effect produced by the same coil may vary from time to time even under the same conditions of operation, as far as they are under the control of the operator. This element of uncertainty is eliminated in the alternating current, for as the vibrating hammer is not required, and a variety of other co-operating conditions necessary to secure a given result in an induction coil may be disregarded, an alternating apparatus is at once simpler, and the results aimed at are more definitely attained.

The field, then, for which the sinusoidal current is peculiarly suited is that of *muscular stimulation*, where it accomplishes its results without the disagreeable incident of sensory irritation.

FIG. 72

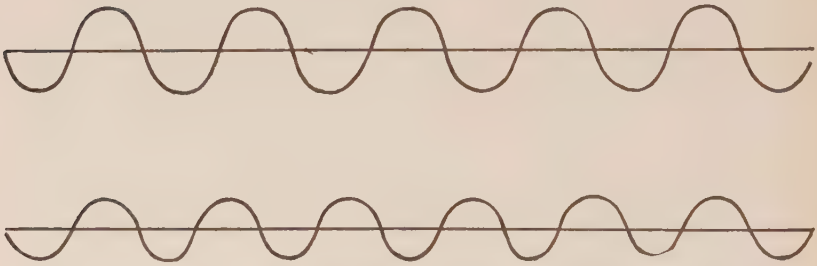


Figure 72 represents curves produced by a magneto-electric apparatus, used by Dr. Kellogg, of Battle Creek, Michigan, and shows great uniformity in the action of the machine.

FIG. 73

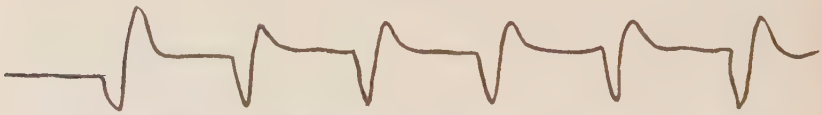


Figure 73 represents a curve from an ordinary inductive coil, used for therapeutic purposes.

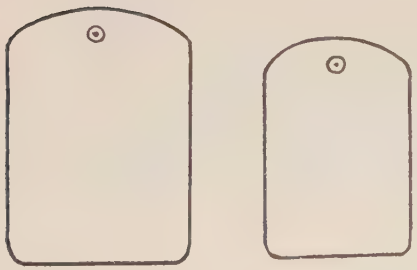
It thus appears that a properly constructed sinusoidal apparatus lends itself to perfect control and may be regulated simply by adjusting its speed, and all gradations of effect may be obtained from mild to strong tetanic muscular contractions.

As metabolism depends largely upon the vigorous

action of nonstriated muscular tissue, it must be apparent that a painless but efficient method of stimulation, such as the sinusoidal current provides, must possess many advantages.

Dr. Kellogg found by experiment that the lifting power, as shown by a dynamometer, was greatly increased by the application of the sinusoidal current, and that in a similar manner the sense of fatigue, after muscular exercise, was abolished. The results correspond with those obtained by Dr. G. V. Poore and Capriati, quoted above, in relation to the action of the direct current.

General Electrization by the Electric Bath. — For this purpose the direct, induced, or sinusoidal current may be selected according to the indications. This method of applying general electric treatment has the following advantages:



(1) Water, as a conducting medium, adapts itself completely to the surfaces of the body;

(2) By moistening the surfaces of the body it lowers resistance, and increases the comfort of administration;*

(3) When suitably heated it protects against exposure and keeps the body comfortable; and

*See, however, opinion of Leduc, footnote, p. 79.

(4) It secures simultaneous application of the current where several areas require treatment.

Method of Administering Bath Currents.—Two copper plates, provided with binding posts, are placed, one at the head and the other at the foot of a porcelain tub. (*Fig.* 74.) The former may measure sixteen by twelve inches, the latter may be somewhat smaller. The feet may be allowed to touch the lower

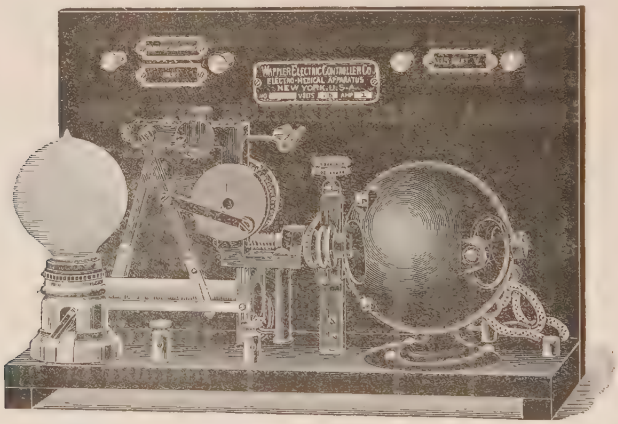


Fig. 75.

electrode, but the head and shoulders are prevented from touching the upper electrode by a rest made of wood or other suitable material.

Figure 75 represents an instrument manufactured by the Wappler Electric Controller Co., for the purpose of furnishing sinusoidal currents for therapeutic use. The current from a switchboard is passed through the instrument and transformed into a sinu-

soidal current. The pole is automatically changed, and the frequency regulated according to the will of the operator. The objection to sinusoidal currents, obtained from an alternating dynamo, is the fact that the frequency of their polar changes, usually about sixty per second, is not subject to regulation. Sixty complete, or one hundred and twenty half cycles per second, is too rapid an alternation for many therapeutic purposes. For some purposes one cycle per second may be desirable, or a still lower alternation. Therefore an instrument which produces a true sinusoidal current, capable of perfect regulation as to frequency, has many advantages.

CHAPTER X

ELECTRICAL TESTING

The testing of nerves and muscles has for its object the determination of the integrity and health of the ganglia from which motor and sensory nerves issue. The testing of muscles which derive their nerve supply from the spinal cord is, in effect, an effort to ascertain whether the reflex arc is complete, and, if impaired, to locate the area of damage. The same remark applies to the testing of the cranial nerves and muscles which they innervate.

In order, then, to determine how far nerves and muscles in any given case depart from their normal behavior under electrical testing, one must be familiar with their behavior in health. If the indifferent electrode be applied to any convenient part of the body, and the testing electrode (*Fig.* 76), having a key for conveniently making and breaking the circuit, and a diameter of a quarter of an inch or more, be placed upon a superficial nerve, as, for instance, the ulnar nerve at the elbow, a muscular contraction becomes visible at the closure of the circuit, when the current has a strength of about one milliampere, and the order in which the contractions appear as the strength of the current increases is as follows:

(1) Kathodal closing contracting (K C C).

(2) Anodal closing contraction (A C C).

(3) Anodal opening contraction (A O C).

(4) Kathodal opening contraction (K O C).

These observations, however, will need constant correction, for it is observed, as we move the testing electrode to different parts of the body, that

(*a*) Nerves that are superficially situated respond to a weaker current than those which are deeply located;

(*b*) Nerves of infants require larger currents than those of adults;

(*c*) Nerves that have been affected by injections of curare do not transmit stimuli to the muscles which they inne rvate, though both direct and induced currents applied directly to muscles whose nerves are thus treated excite contractions. Such contractions are, however, somewhat less brisk than when the nerves have been thus treated.

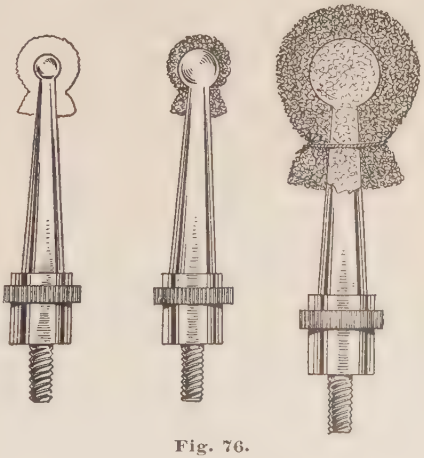


Fig. 76.

It is readily observed that the contractions produced in muscles are due to the making and breaking of the current, and that the muscles remain quiescent while the current is traversing them. This is practically true, though more sensitive methods of study

show the presence of a "contraction remainder," due, possibly, to slower relaxation of the sarcoplasm or muscular sheath. With still stronger currents than are usually employed in electrical testing, there is noted an imperfect tetanus, called "duration tetanus."

Researches into the behavior of muscle under electrical stimulation have shown that the striated muscular fibers and the investing sarcoplasmic element have a different rate of response to electrical stimulation, the former contracting rapidly with a longer period of repose, the latter contracting more slowly with a shorter period of repose.

Intermittent Currents.— If now we use induced currents or interrupted direct currents, we shall note, where the interruptions exceed twenty per second, that the muscles pass into a state of tetanus. This follows from the fact that a muscular contraction requires about one tenth of a second for its completion. When, therefore, the stimuli occur oftener than ten times per second, the contractions tend to fuse and produce a tetanic effect. From what has been said in Chapter III, on the physics of induced currents, it may readily be inferred that, owing to the irregularity of the impulses proceeding from induced currents, it is better to employ an interrupted direct current in electrical testing.

According to Leduc, electrical testing is most successfully accomplished with currents in which the interruption occurs one hundred times per second, and produce waves lasting one thousandth of a second with a period of repose lasting nine thousandths of a second.

Non-striated Muscle.— When non-striated muscle is stimulated by the electric currrent, it responds, as it does to other stimuli, sluggishly. It may, therefore, be inferred that the current most suitable for stimulation of non-striped muscular fiber is a current of slow interruptions. Experiment has shown that probably the anode is the most suitable pole for stimulating such tissues.

Electric Currents as a Test for Death.— These afford a perfect demonstration of death, for when the muscles cease to contract under the influence of induced currents, it may safely be inferred that life is extinct, or if they do contract, that death has been of very recent occurrence, and cadaveric rigidity has not yet set in. It has been shown that irritability to induced currents after death disappears first, and that responses to direct currents persist for some time longer. This fact might readily afford a clue as to the time at which a death has occurred.

Testing of Sensory Nerves.— Elsewhere in Chapter IX we have already analyzed the sensory effects produced by direct, induced, and sinusoidal currents, showing that in direct currents the sensation is due to chemical action, in induced currents largely to the abruptness of variation in potential as shown by tracings on a moving plate, and to varying relations between the number of interruptions per second, the degree of intensity of the current, and the ratio between the length of the curve and the period of repose; and that in sinusoidal currents the sensory effects are greatly reduced, owing to the gradual

change of intensity as evidenced by the sine curve. It may be added that in proportion as the curve approaches a true sine curve, the sensory effects are reduced. When the electrodes are moistened by fluids containing salts, it is found in administering direct currents that with a solution of sodium chloride there is more irritation at the positive pole, owing to the fact that sodium ions are entering at that point on their passage to the negative pole, and with a solution of sodium bicarbonate the negative pole is the more irritating, because the CO_2 radicle, being electro-negative, is liberated and carried through the skin on its way to the positive pole. Irritation will, of course, increase in proportion to the decrease in the size of the active electrode, as with a given current the density increases with the decrease in the area of the electrode.*

The anesthetic effects of induced currents have already been referred to in Chapter V, on the physiology of induced currents.

When moving a small electrode over the surface of the body, it is found that whenever the electrode is over a sensory nerve trunk the sensation becomes more painful, and that the nerve trunk is more sensitive than its cutaneous ramifications. It is well to ascertain these points in testing, and avoid them if possible. One may determine them readily by exploring. Several may be found on the dorsum of the foot when testing for the reaction of the interossei.

Nerves of Special Sense.—If the optic nerve is stimulated by an electric current, a sensation of

*See footnote, p. 79.

light is experienced; if the olfactory nerve be included in the circuit, an odor like phosphorus is noticed. If the nerves of taste are stimulated there originates a metallic taste, and a perception of sound follows stimulation of the auditory nerve. Each nerve of special sense, therefore, when stimulated, produces a sensation peculiar to itself.

The Effects of Electrical Currents on the Brain.— When a continuous current is passed transversely through the brain a sensation of giddiness is produced, with a tendency to fall toward the side on which the positive pole is placed. Sometimes there is conjugate deviation of the eyes toward the kathodal side and lateral nystagmus.

The disturbance of equilibrium above noted may be due to an exalted irritability upon the side of the kathode, with diminished irritability upon the side of the anode, or it may be due to a specific action upon the semicircular canals. Induced currents produce no such effects when applied to the skull, probably because, owing to the diffusion of the current, only a small quantity passes through the cerebrum.

Professor Leduc, as the result of experiment, has concluded that negative applications to the brain stimulate its functions, while positive applications have a quieting and depressing action.

Thoracic and Abdominal Viscera.— From what has already been learned of the effect of those types of currents thus far studied, it could fairly be concluded that they would exert a stimulating effect

upon glandular secretions and upon peristaltic action, and the clinical use of these currents amply confirms these conclusions.

Motor Points.— In testing muscles the testing electrode is placed over the point where the greatest muscular contraction is secured with the least current. These points upon dissection are found to be the points where the main nerve enters the muscle. They are found to vary somewhat in different subjects,

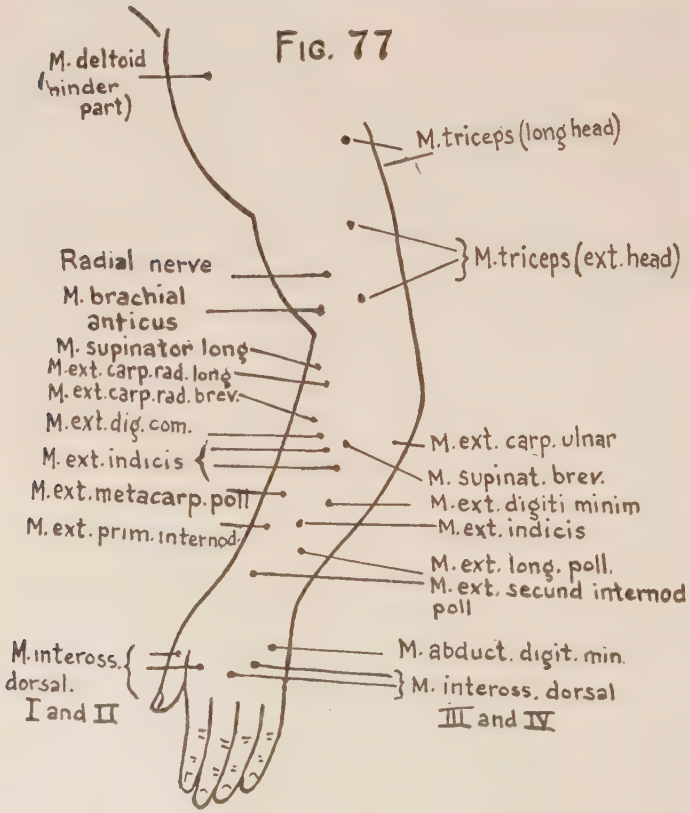
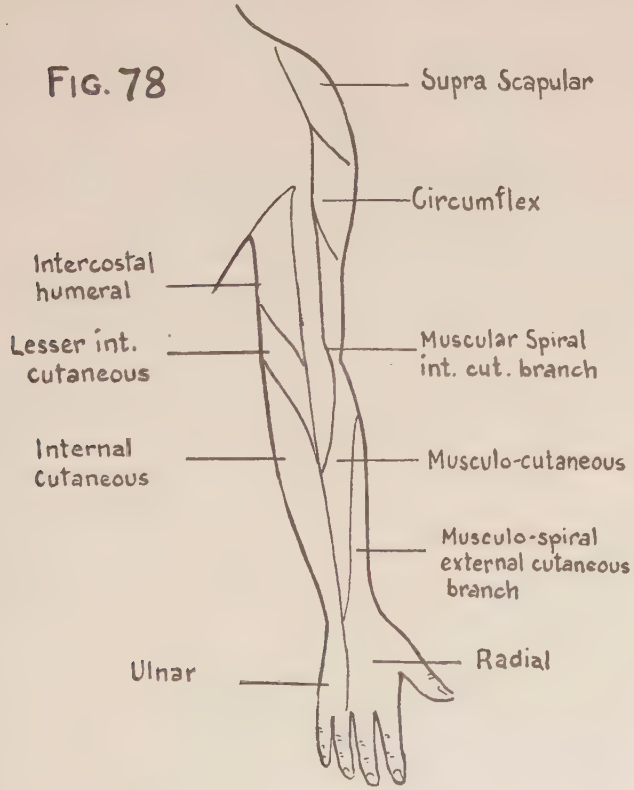

M. deltoid (hinder part)
M. triceps (long head)
M. triceps (ext. head)
Radial nerve
M. brachial anticus
M. supinator long
M. ext. carp. rad. long
M. ext. carp. rad. brev.
M. ext. dig. com.
M. ext. indicis
M. ext. metacarp. poll
M. ext. prim. internod.
M. ext. carp. ulnar
M. supinat. brev.
M. ext. digiti minim
M. ext. indicis
M. ext. long. poll.
M. ext. secund internod poll
M. inteross. dorsal. I and II
M. abduct. digit. min.
M. inteross. dorsal III and IV

Fig. 77

and the amount of current required will, of course, vary with the amount of subcutaneous fat present. These motor points for the whole body have been carefully plotted out, and are well displayed in



Ziemssen's plates, of which Figures 77 and 78 are illustrations, the former showing the motor points for the dorsal aspect of the arm and hand, the latter, the cutaneous distribution of nerves in the same location.

The student will find it a useful exercise to verify these points and areas upon his own body, in order that he may learn the behavior of normal muscles under electrical stimulation, and be prepared to recognize such deviation as may appear in actual practice.

Testing should begin with the interrupted, and end with the continuous current. When using the continuous current the student should begin with a pressure of about twenty volts applied to a muscle of the lower extremities. He should use the kathode, and, watching the milliamperemeter, should note when the closing contraction is obtained. He should then move the electrode in order to find the best point for securing such contraction. He should then compare the anodal closing contraction with the kathodal closing contraction, and note whether the contraction is brisk or sluggish. He should next apply the electrode to the nerve trunk and notice its effect upon the muscles which it supplies. Corresponding portions of the body may be compared. In case of bilateral affections the student may make comparison with his own electrical reactions.

Changes in Electrical Reactions.— We are now prepared to analyze effects produced by electrical stimulation. These may be embraced under two heads: (a) quantitative and (b) qualitative. The former refers to variations in the quantity or amount of response to electrical stimulation. The latter has reference to changes in the quality or character of the response to such stimulation. Under this class may

be included the reaction of degeneration, the myotonic reaction, and the myasthenic reaction.

Quantitative Reactions.— These do not have very great value, because there is a certain range of variation in the responses of normal muscular tissue. Again, variations may be due to the degree of cutaneous moisture, to the location of the testing electrode with reference to the motor point, to different degrees of pressure of the electrode, or to differences in resistance of the skin which manifest themselves during the test. Certain inferences, however, may be drawn with caution. If by comparison with one side the muscular reactions are produced with a weaker current than is necessary to produce similar contractions upon the other side, an increased excitability may be inferred. Where both sides are affected, comparison may be made with currents necessary to produce similar contractions in patients whose condition is normal.

Where there are marked variations in quantitative reaction this method furnishes positive results. Increased irritability usually accompanies disease in which there are exaggerated reflexes, diminished irritability in which there is a tendency toward abolition of reflex action. We might, therefore, fairly expect to find the former in chronic myelitis, degeneration of the lateral columns, hemiplegia, etc., and the latter in acute anterior poliomyelitis, neuritis, fatigue, etc.

Qualitative Reactions.— Here we have to consider the reaction of degeneration, a term intro-

duced by Erb, to signify chiefly a delayed or sluggish response to muscular contraction under the influence of the direct current. Normal muscle, in its response to electrical stimulation, contracts promptly; muscles showing the reaction of degeneration respond sluggishly to the direct current, and not at all to rapidly interrupted currents. In like manner nerves showing the reaction of degeneration give no response to electrical stimulation, while muscles similarly affected do not always show a decreased contractile power. They may, indeed, show a stronger response than normal muscular tissue, but if they show the reaction of degeneration, their response will be slow and retarded.

Conditions Leading to the Reaction of Degeneration (*written R D for brevity*).— Where R D has been found we may infer (*a*) that there has been destruction of one or more cells of the anterior horns of the gray matter of the spinal cord, as in anterior poliomyelitis; (*b*) that there has been a corresponding damage to the nucleus from which the cranial nerve proceeds; or (*c*) that there has been section or other damage to a nerve trunk. R D does not follow paralysis of cerebral origin unless the nucleus or the cranial nerve, which issues from it, has been involved. It does not occur in diseases of the white matter, nor in hysterical paralyses.

Longitudinal Reaction.— By this is meant the observed fact that when the testing electrode is applied to the motor point of a muscle showing R D, the motor response is less than when it is applied to

the distal end of the muscle. As this is a reversal of the rule in healthy tissue, it is a significant and important observation.

Partial Reaction of Degeneration.— It was noted above that in the complete reaction of degeneration muscles do not respond to rapid interruptions of the current. If, however, partial degeneration is present, some contractile power may remain. Therefore it is necessary, in order to avoid the danger of concluding that the muscles are normal, to supplement the test with the direct current which will reveal the usual sluggishness of response.

Conclusions as to the Value of These Tests.— Tests made with the direct current depend largely for their value upon the recognition of the sluggish action of the muscles. As the degree of response is a matter of the operator's judgment, it can readily be seen, in the absence of any precise standard of measurement, that the method, while it affords *data* for diagnosis in many cases, is yet lacking in positiveness and certainty, more especially in estimating the degree of possible damage.

Absence of response, both in nerve and muscle, to the stimulation from rapidly interrupted currents points to the conclusion that the cells from which the muscles receive their nerve supply have been damaged. If the muscles respond to rapidly interrupted currents, but contract sluggishly to the stimulation of direct currents, the inference would be that the damage was less extensive. The use of the direct current serves to correct erroneous conclusions drawn

from the action of induced currents, and to confirm these conclusions when they are properly drawn.

Myotonic Reaction.— Reference has already been made to the fact that while apparently there is a complete subsidence of the effect of electrical stimulation succeeding a muscular contraction, yet a portion of the effect continues. This occurs in normal conditions. In Thompsen's disease, however, both continuous and interrupted currents throw the muscle into tetanic contraction, which persists from five to thirty seconds after the testing electrode is removed.

Myasthenic Reaction.— This occurs in grave myasthenia, where the muscle has been tetanized for some time by the interrupted current. After a time a decided decrease in the amount of response ensues, but if a single closing contact be made with the direct current, the electric response is as vigorous as it was before the tetanization.

CHAPTER XI

ELECTRICAL DIAGNOSIS

Oersted's Experiment.— In Chapter II, on the physics of the direct current, we called attention to the fact that the passage of an electric current through a wire running parallel to a magnetic needle deflects it. This observation was first made by Oersted.

Figure 79 represents an apparatus for conveniently illustrating this law. The instrument is set

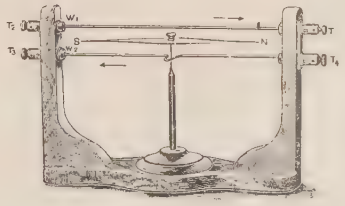


Fig. 79.

in the magnetic meridian and a current passed from the south to the north seeking pole of the magnet, whereupon the needle is deflected to the left of the observer facing the north. A convenient rule for

determining the direction of the deflection was formulated by Ampere, and is referred to in the same chapter.

Such an apparatus, when strengthened by the addition of several coils of wire, is called a multiplier. When combined with a graduated scale it becomes a galvanometer. When for medical uses the scale is graduated in one thousandths of an ampere, it is called a milliamperemeter or milammeter. Originally these instruments were constructed so that the needle moved only in a horizontal plane and under the influence of the earth's magnetism. In the later types used for medical purposes the needle is placed in the field of a horse shoe magnet, and being independent of the earth's magnetism, the instrument may be set in either the horizontal or perpendicular position. Moreover, the needle is dead beat, that is to say, it does not oscillate, but indicates its readings without preliminary movements over the graduated scale. Neither is it affected by stray magnetic fields in its neighborhood. This is the D'Arsonval type of instrument. (*Fig.* 80.) In a later type the needle is replaced by a slender moving coil which transmits the current and becomes magnetized by it. (*Fig.* 81.)

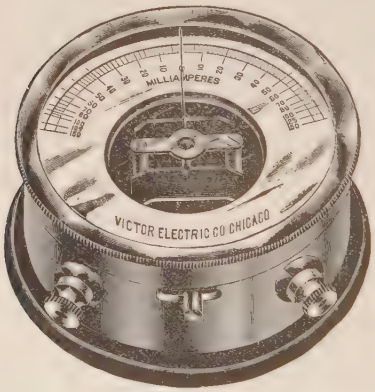


Fig. 80.

Milliamperemeters are frequently constructed with a shunt circuit providing two readings upon the dial, one for larger and one for smaller currents. To use the scale containing the finer subdivisions a portion of the current is carried through a shunt controlled by a plug.

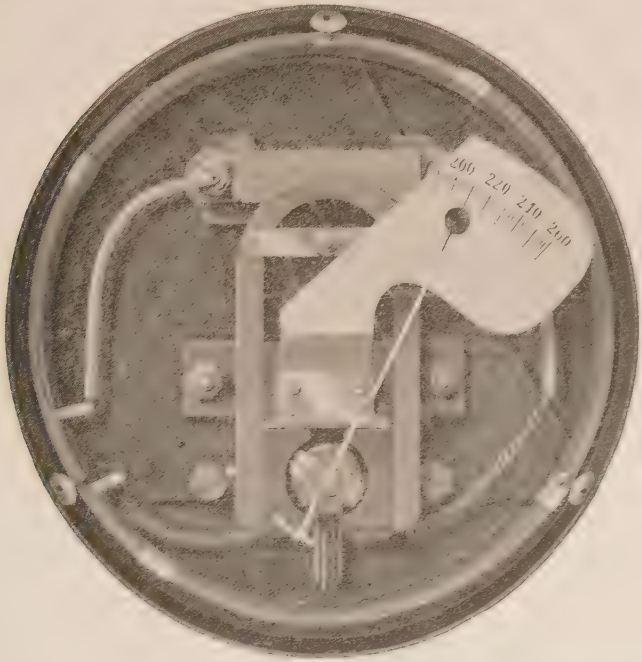


Fig. 81.

VOLTMETERS.— When it is desired to obtain the voltage of a current an ammeter may be conveniently used for that purpose. This, however, is accomplished by means of a resistance coil placed in series with the ammeter. Assuming that a gal-

vanometer has a resistance of twenty ohms, it may be connected with a resistance coil of nine hundred and eighty ohms, making a total of one thousand ohms. Now as $C = \frac{E}{R}$, when the ammeter records one milliampere we know that one volt is passing, since $C = \frac{1}{1000} = 1$ milliampere. Thus the reading in milliamperes will give the reading in volts.

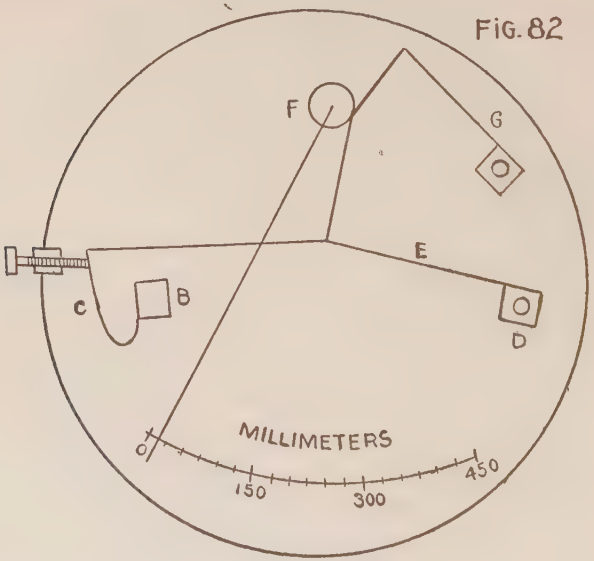


FIG. 82

HOT WIRE AMMETER.— For registering alternating currents advantage is taken of the fact that electric currents in passing through a wire are attended with the production of heat. The expansion of a metal resulting from heat is made to move an index along a graduated scale and record the volume of current passing through the wire. Figure 82

illustrates a hot wire instrument calibrated as a milli-amperemeter. E is a platinum-iridium wire stretched between B and D by means of a spring C. A thread connected with the middle of the wire passes over the wheel F, which takes up the slack in the thread by the action of the spring G, and the index A attached to the wheel F moves along the graduated scale. The same instrument by suitable graduation may serve as a voltmeter.

Electro Cautery.— An electro cautery consists of a loop of platinum or platinum-iridium fashioned into different patterns according to the purpose for which it is designed and mounted upon copper supports, which are insulated from each other by varnish or waxed thread. These are fastened together in a convenient form for insertion into a cautery holder. Figure 83 represents a group of cautery electrodes.

An excellent cautery holder is represented in Figure 84, made by the McIntosh Battery & Optical Company. This is adapted to hold either an electro cautery, such as has already been described, or a snare for use in nasal or pharyngeal work. The holder is provided with a circuit breaker and a milled snare wheel for operating the snare. As platinum has a high resistance, it becomes heated by the current.

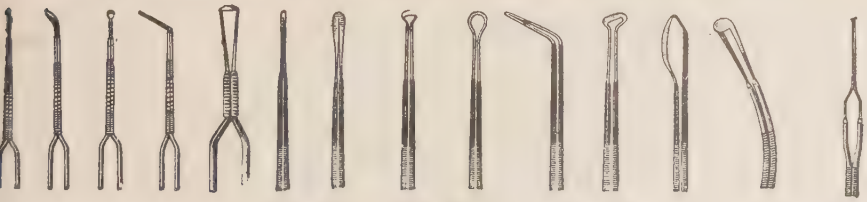


Fig. 83.

The heat required for ordinary cautery work is evidenced by a dull redness. A white heat cuts like a knife, and may leave the vessels open instead of searing them. Currents necessary to heat small cauteries to a red heat range from eight to ten amperes. The current necessary to heat the cautery devised by

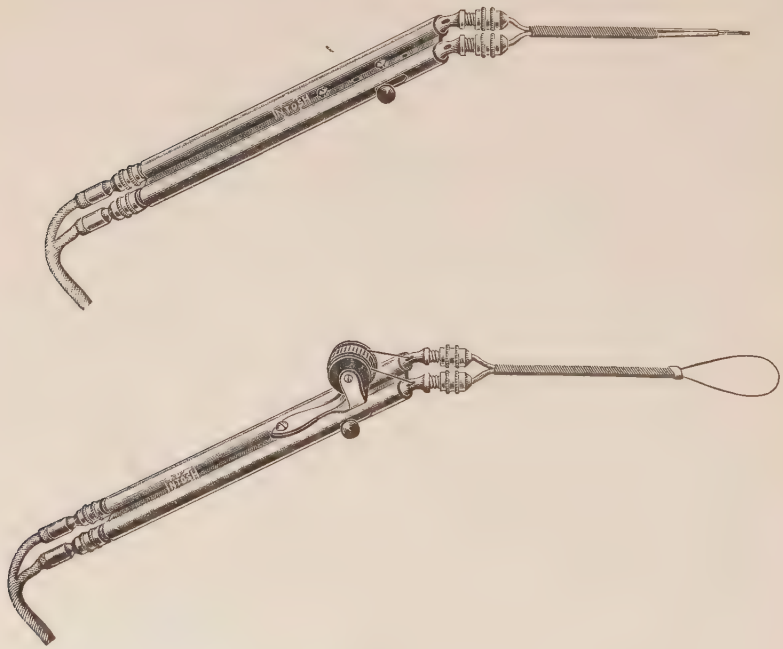


Fig. 84.

Professor Bottini for the treatment of enlarged prostate requires a current of fifty amperes. Such an instrument consisting of two large strips of platinum or platinum-iridium lying side by side in the beak of the instrument and having a resistance of

about .0005 ohm would necessarily require a large current to heat it.

Figure 85 represents Bottini's modified prostatic incisor with threaded regulator for controlling the

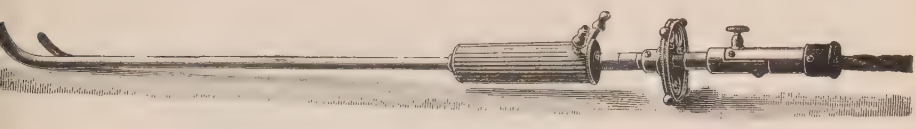


Fig. 85.

platinum-iridium blades. The distance between the beak of the instrument and the platinum-iridium knife is indicated in millimeters on a scale below the regulating wheel.

For heating electro cauteries primary or secondary batteries may be employed where the commercial currents are not available. Where primary batteries are employed, bichromate cells are preferable, since they furnish a strong current for a brief time. Figure 86 is an illustration of a battery containing six cells, which can be arranged in parallel for electro cautery work or in series for diagnostic lamps. A ratchet attachment enables the operator to remove the elements from the solution or immerse them to any depth required.

Accumulators may also be used wherever there are facilities for charging them. They may have from four to six cells furnishing an E. F. M. of from 1.85 to 2 volts per cell.

The commercial mains may be employed as already described in Chapter VI (*Fig.* 46) by combining an alternating dynamo with a transformer and thus reducing the voltage and increasing the amperage in the proportion needed.

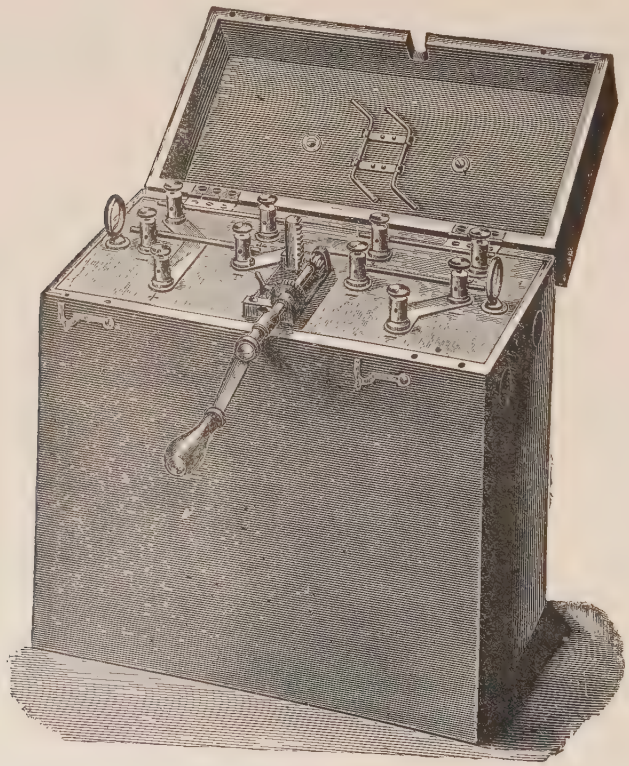


Fig. 86.

Conductors.— Thick copper wires should be used for conduction of currents for cautery use, in order not to consume the current outside of the

platinum loop in unnecessary resistance. Suppose a cautery has a resistance of .04 ohm and requires a current of twenty amperes to bring it to a red heat. Let us suppose that by use of a transformer we obtain a pressure of five volts. Then as $R = \frac{E}{C}$, the total resistance of the circuit would be .25 ohm. Assuming the conductors two meters in length with a resistance of 0.0014 ohm per meter, making a re-

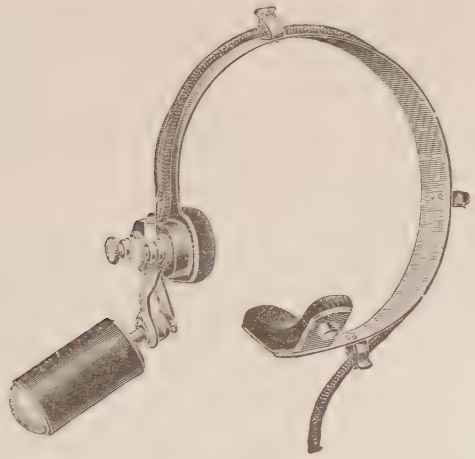


Fig. 87.

sistance of 0.0028 ohm, we shall then have as the total resistance of the circuit 0.0028 + .04 = 0.0428 ohm. This leaves a margin for rheostat and imperfect contacts of .25 — 0428 = .2072 ohm, which is more than sufficient.

Diagnostic Lamps. — Small lamps may be attached to various diagnostic instruments, as laryngoscopes, otoscopes, and vaginal and rectal specula.

In nose and throat work the light from an argand burner reflected from a head mirror still continues to meet with greatest favor. Instead of an argand burner a forty or fifty candlepower electric lamp with ground glass or frosted globe, to cut off the reflection of the filament, may be advantageously used.

It would seem that the Nernst lamp, which substitutes a core made of a combination of the rare earths for the ordinary carbon filament of an incandescent lamp, would be admirably adapted for nose and throat illumination.

For illumination of diagnostic lamps connection may be made with the commercial mains, or primary or secondary batteries may be used. Where a wall plate (*Chap.* VII, *Fig.* 57) or similar arrangement is not in use, it is desirable to use a rheostat of German silver wire, furnishing a resistance of six or eight ohms. Small lamps for diagnostic purposes are of about one candlepower and consume about four watts. Since a watt is the product of the voltage into the amperage, it can readily be seen, that where the voltage is high the amperage will be small. Thus, if a ten-volt lamp takes .4 of an ampere, a five-volt lamp would take .8 of an ampere.

Head lamps (*Fig.* 87) are sometimes convenient for diagnostic purposes, and where sufficient candlepower is furnished serve the purpose very well. Such lamps, however, in the author's experience do not afford sufficient illumination and are inferior to the head mirror reflecting light from a stationary source.

The Antrum Lamp.— This is a most useful lamp in oral surgery (*Fig.* 88). It consists of a small lamp of four candlepower attached to a curved stem and surmounting an ebonite disk to protect the

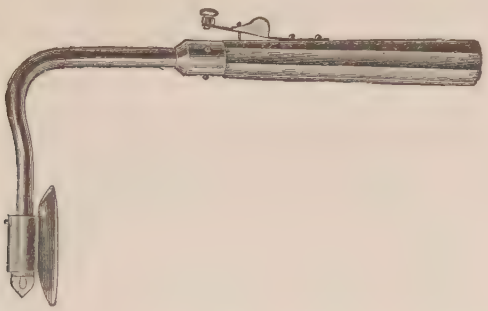


Fig. 88.

tongue. When the patient is examined he is placed in a dark room. The light from the lamp shines through the intervening septa and lights up the face with a red glow. If there is pus in either antrum, it is revealed as a dark shadow under the eye upon

Fig. 89.

the affected side. Figure 89 shows an instrument for transillumination of the frontal sinus. A condenser is blown on the end of the incandescent bulb, which increases the penetrating power of the rays. Side lights are shut off by means of a rubber shield. When used for transillumination, contact with the

instrument is made in the inner and upper border of the orbit.

Gastrodiaphane.— This is an instrument (*Fig.* 90) for transillumination of the stomach. It consists of a flexible rubber tube about twenty-six inches long, conveying two wires which are connected

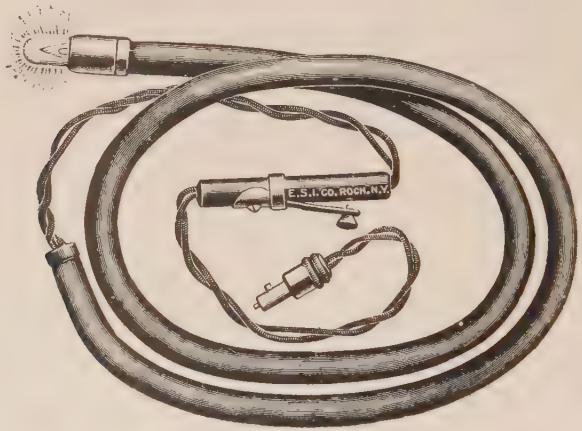


Fig. 90.

with a small lamp in the end of the tube. As in all cases of transillumination, the patient is examined in a dark room. The tube is swallowed, and the light of the lamp is perceived through the intervening walls. The stomach should contain about eight ounces of water. When the whole stomach is revealed gastroptosis may be inferred, as in its ordinary position, owing to the interference of the liver and intestines, only the lower part is translucent. When there is dilatation the upper border is not visible and respiratory movements may be observed. When

gastroptosis is present respiratory movements are not recognized, the stomach being too far below the diaphragm to be affected by the latter's movements.

THE CYSTOSCOPE.— This is a most useful instrument, permitting the surgeon to obtain a view of the interior of the bladder. Figure 91 represents Dr. Nitze's simple examining cystoscope, manufactured

Fig. 91.

by the Kny-Scheerer Company of New York. It consists of a tube suitably bent to permit its introduction into the bladder, and containing at its distal end a light set at an angle to illuminate the area under examination. Near the lamp is a small lens, beneath which is a prism which reflects the image through a series of lenses to the operator. The proximal end of the telescope is fitted with an eye-piece and a button indicating the position of the beak. This instrument may be modified by the addition of a tube and cocks for irrigating the bladder, and by the addition of a second prism for observation of the neck of the bladder and the prostate gland. Figure 92 represents a double ureter and irrigating cystoscope

Fig. 92.

manufactured by the same company. Here the telescopic attachment is removable. A catheter guiding attachment is fitted to the distal end of the instrument, controlled by a lever at the proximal end which raises or lowers the tip of the catheter to guide it into the ureter.

Valentine's urethroscope (*Fig.* 93) consists of an endoscopic tube into which is introduced a small incandescent bulb mounted on a long rod which carries

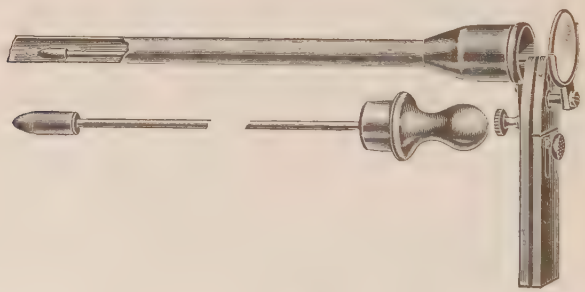


Fig. 93.

the bulb to the distal end of the tube. A circuit switch is placed near the handle.

A vaginascope with a light carrier and a circuit switch is represented in Figure 94. Similar instruments for illumination of the various cavities of the body may be found described in the catalogues of the manufacturers of electric light apparatus. They are highly interesting and many of them very ingenious, but manifestly cannot

Fig. 94.

all be reviewed in this chapter. We may, however, call attention to Casper's panelectroscope (*Fig.* 95),

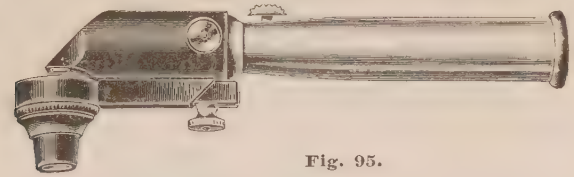


Fig. 95.

containing condensing lens and prism, which may be used for illuminating the rectum, male urethra, and female bladder and vagina, and has been adapted by Dr. Killian for illumination of the ear, nose, throat, and esophagus.

Electro-Magnets.— These may be used for removing particles of iron or steel from various parts of the body, particularly from the eye. Where the particle is somewhat large and not firmly fixed it is often successfully removed. Where it is small and firmly fixed, even a large magnet is not likely to remove it. There has been much discussion as to the comparative value of hand magnets and giant magnets in removing particles of iron or steel. The greatest difficulty consists in removing small particles, and it can readily be seen that these soon reach the limit of magnetic

Fig. 96.

saturation, and that therefore in these cases a large magnet will do nothing more than a small one. Figure 96 represents a hand magnet made by the McIntosh Battery & Optical Co. When connected with one cell it will lift three hundred grains; with

Fig. 97.

seven cells seven hundred and twenty grains. Figure 97 (Victor Electric Co.) represents one of the larger magnets used for removing particles of iron or steel from the eye. If a particle is large, particularly if it

is to some extent fixed, the larger magnets are the more serviceable.

Ozone.— Wherever high potential charges occur a certain amount of ozone is developed, together with nitrous and nitric oxides. The composition and nature of ozone are not accurately determined. It may be a molecule of oxygen with an additional atom of oxygen forming the molecule O_3, or it may be an energized form of oxygen, due to dissociation of the atoms in an oxygen molecule. In other words, it may be " nascent " oxygen. It has been prepared for therapeutic use in pulmonary cases and for purposes of disinfecting or enriching contaminated or poorly oxygenized air. As shown by Dr. Bordier it has been fatal to guinea pigs even in minute proportions, proving highly irritating to the respiratory tract. The French have recommended it particularly in cases of pertussis. The results obtained in phthisis are not conclusive. Figure 98 represents an apparatus made by the Wagner Co., of Chicago, which consists of two concentric glass tubes with an air space between. The passage of the high potential current through the inner tube generates ozone in the outer

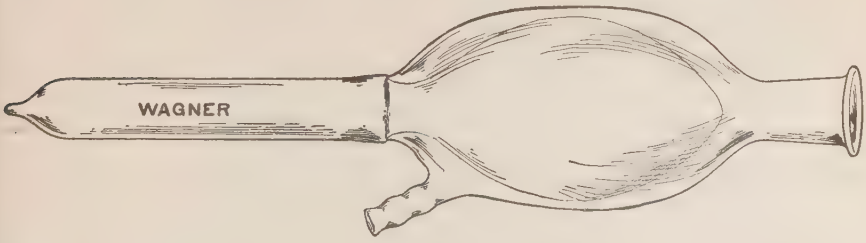


Fig. 98.

tube, which may be carried into the lungs of the patient by air pressure. It has been recommended that the air in the outer tube be charged with volatile oils from a nebulizer with the expectation that these vapors will absorb the nitrous and nitric oxides generated by the current. A more certain method of eliminating irritating vapors would be to connect the outer tube with a tank of oxygen. In Figure 99 the manner of using ozone for therapeutic purposes is clearly shown. The inner tube is connected by a conductor with a generator of high tension or high frequency discharges. The outer tube is connected with a hand nebulizer and bulb by which volatile oils are forced through the nozzle into the lungs of the patient. Instead of the hand bulb, connection may be made with a compressed air apparatus or, as suggested above, with a cylinder of compressed oxygen. It would seem that this simple combination, modified

Fig. 99.

as suggested above, possesses all the virtues of the larger and more expensive apparatus upon the market and amply suffices to test the value of ozone as a remedial agent. While the nitrous and nitric oxides cannot be entirely eliminated, since oxygen is not supplied in tanks without a certain proportion of atmospheric air, there would yet be a considerable reduction in the volume of noxious gases, which could be further controlled by the use of volatile oils as above described. Figure 100 represents an apparatus made by the Ozone Pure Airifier Company, of Chicago, for the disinfection of imperfectly ventilated rooms by means of ozonized air. The ozone is produced by the discharge of high potential currents.

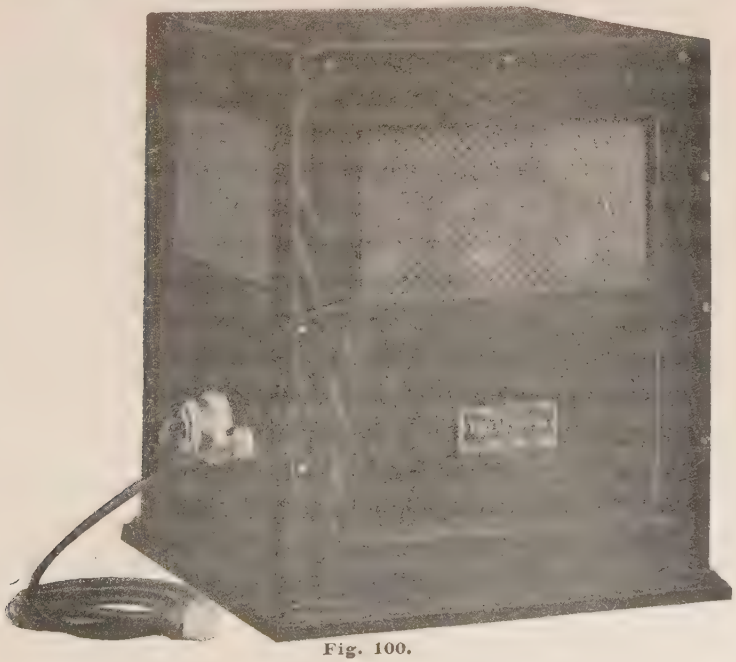


Fig. 100.

CHAPTER XII

PHYSICS OF STATIC ELECTRICITY

Up to this time we have been engaged in the study of current electricity or electricity in motion. We shall now give our attention as briefly as is consistent with clearness to the study of static electricity, or electricity at rest. Let it be premised, however, that electricity in the static form is not a different kind of electricity from electricity in motion. Electricity is always the same, yet manifesting itself under different conditions. Here, as elsewhere, like electricities repel and unlike attract each other, but we have in static electricity phenomena produced by stresses in insulating or dielectric media, which are of a highly interesting nature. Static electricity is developed when two bodies of different material are brought in contact. This effect is increased by friction. Thus, if a rod of glass is rubbed by a piece of catskin, plus electricity is developed upon the surface of the glass rod and electricity of opposite sign is developed upon the catskin. In like manner if a rod of vulcanite is rubbed by a piece of flannel, minus electricity is developed upon the vulcanite and electricity of opposite sign upon the flannel. It may be remarked in passing that the designation of the electricity produced

upon the glass as positive and that upon the vulcanite as negative is founded upon custom, and is purely arbitrary. The important fact is that the electricities are of opposite sign.

The original experiment attributed to Thales, who lived over six hundred years before Christ, and who found that when amber, which the Greeks called *electron*, was rubbed, it would attract to itself light particles of matter, was an experiment in static electricity. So that we may say that this variety of electrical phenomena was not only the earliest produced by experiment, but, in the electrical disturbances of thunder storms, continues to be, perhaps, the most impressive and startling of the manifestations of nature.

In modern times Otto Von Guericke, of Magdeburg, invented a sulphur ball from which sparks were produced by the friction of the hand. (*Fig.* 101.)

The Electrophorus.— In the evolution of the modern static machine used for therapeutic purposes, it becomes necessary for us to study the action of the electrophorus. This (*Fig.* 102) consists of a shallow circular pan or tin or other metal filled with a layer of resin.

Fig. 101.

Upon this is placed a disk of the same metal with an insulated handle of vulcanite or sealing wax.

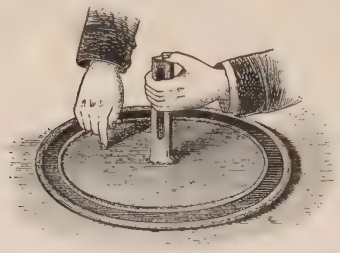
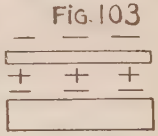


Fig. 102.

This simple device will go far toward enabling us to solve the mysteries of the generation and production of static discharges in the static machine. If now the metal disk is removed from the resin and the latter is struck several times with a piece of flannel, and the metal disk replaced, the negative electricity of the resin will attract electricity of opposite sign to the under surface of the metal disk and repel electricity of like sign to the upper surface, thus: (*Fig.* 103) If a finger touch the metal disk, the minus electricity escapes to the earth, leaving the plus electricity bound upon the under side. If now the disk be removed it will be found to be charged with plus electricity, which will leap out with a spark if the knuckle be presented to it.

Fig. 103



Revolving Electrophorus.— We may convert this device into a revolving electrophorus and observe its behavior and analyze the results obtained. In Figure 104 A is a glass plate, B a sector of vulcanite, which is about two centimeters

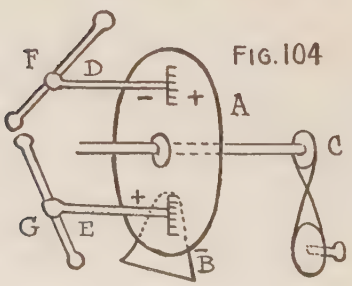


Fig. 104

behind the plate and acts as an inductor. This takes the place of the vulcanite in the electrophorus above described. Near B is a rod E carrying a metallic comb, and on the opposite side of the plate is a similar arrangement D. These are terminated by the rods G and F respectively, which act as the prime conductors of the device and are to be regarded as representing the metallic disk in the electrophorus. When the vulcanite is struck with a piece of flannel, negative electricity is developed, and is repelled to the prime conductor G, positive electricity being drawn to the points of the comb. Since electricity passes readily from points, it will be discharged upon the surface of the plate rendering it positive. The plate being now revolved, is brought under the comb D, which immediately discharges negative electricity upon the plate, repelling positive electricity to the prime conductor F. While there is doubtless an original separation of electricity in the conducting system as just described, the sector attracting electricity of one sign upon the plate and repelling electricity of opposite sign to the terminal of the prime conductor on that side, yet it is evident that the whole conducting system upon each side becomes quickly charged with the kind of electricity which is discharged upon the plate upon the corresponding side. The continued revolution of the plate will produce a continuous separation of electricity, and if the prime conductors are brought near enough, a discharge in the form of a bright spark will pass between them.

In an arrangement such as has just been de-

scribed, it is found that the ebonite disk is likely to lose its charge even while the machine is in operation, and may lose it immediately after its motion ceases. The next step, therefore, in the evolution of the static machine is the addition of a device by which the initial charge is maintained. This is represented in Carré's machine, where the vulcanite sector described in the revolving electrophorus is replaced by a glass plate revolving between two cushions, which by the friction of their surfaces upon the plate sets up an inducing charge. The action of the inducing charge is exactly the same as that described above. In Figure 105 D is an ebonite disk which is revolved by a series of wheels C. The combs are readily recognized, one being connected with the rod F and the other with a hollow cylinder E called the prime conductor. F is a rod jointed at N, so that it can be brought near to E. The machine is grounded by a chain. At G is noticed a loop from which a Leyden jar may be suspended. When the machine revolves a succession of sparks will pass between E and F. If a Leyden jar be suspended from the loop G so that its inside coating is connected with the prime conductor, and the rod F

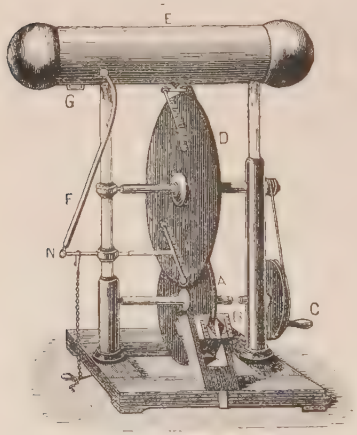


Fig. 105.

is brought near the outer coating, sparks will pass between the jar and the rod, producing a loud report.

In this picture of the evolution of a static machine from the friction of a rod of glass upon a piece of silk, through the electrophorus, the revolving electrophorus and finally Carré's machine, we have described all that is essential to the complete understand-

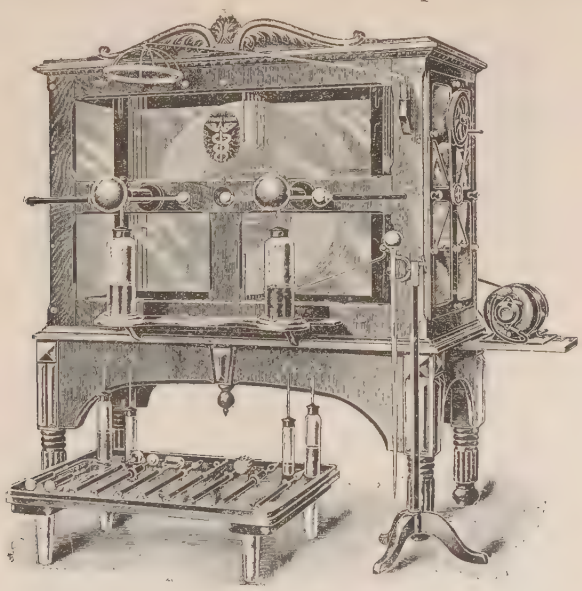


Fig. 106.

ing of a modern static machine. The splendid machines of modern manufacture capable of bridging a space of fourteen inches or more between the prime conductors involve no prinicple not already explained. On the other hand they cannot be understood unless the principles already explained are thoroughly comprehended.

In 1860 C. F. Varley produced a type of influence machine in which six carriers were mounted upon a rotating glass disk. In 1865 Holtz, a German, invented a machine which bears his name, in which

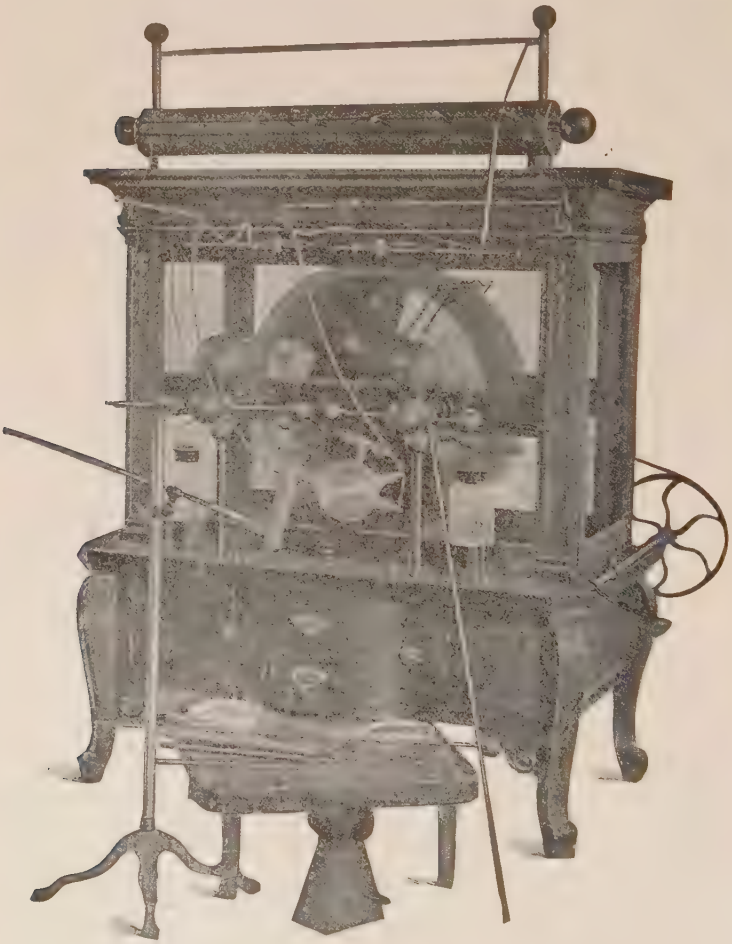


Fig. 107.

electrical separation is produced by induction. The initial charge, however, is furnished by an accessory apparatus. This was the first machine invented which was adequate for therapeutic uses. Figure 106 represents a Holtz machine manufactured by the Waite & Bartlett Manufacturing Company, of New York. In the Toepler machine, invented in the same

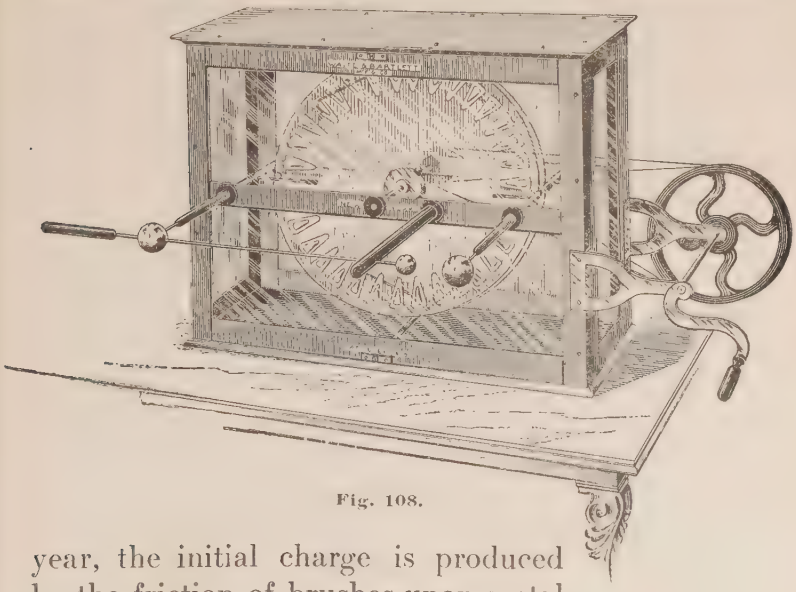


Fig. 108.

year, the initial charge is produced by the friction of brushes upon metal disks fastened to the surface of the external revolving plate. Figure 107 is an illustration of the so-called Toepler-Holtz machine in which the characteristics of both the Holtz and Toepler types are combined.

In 1867 Lord Kelvin invented a machine which was elaborated by James Wimshurst and called by

the latter's name. Of this an illustration is given in Figure 108. As this machine is not used in this country except as an accessory apparatus for furnishing an initial charge to machines of the Holtz type, we shall omit its consideration. In one or the other of these types may be placed every machine of modern manufacture which has received any considerable recognition. There are machines which combine some of the characteristics of one or more types which might be designated as compound. Nevertheless they involve no new principle not already incorporated in the machines above described.

The parts that are common to the Holtz, Toepler, and compound types are: stationary plates with sectors of paper and tin foil or both pasted upon the surfaces, revolving plates, prime conductors, neutralizing rod, and Leyden jars.

The distinctive characteristics of the Holtz type are: a small Toepler or Wimshurst machine to produce the initial charge; each stationary plate divided into an upper and lower section and separated by a small horizontal air gap; each paper sector provided with a set of metal points; no disks or brushes.

The distinctive characteristics of the Toepler and compound types are: metal disks on one or more revolving plates; no gaps in stationary plates; brushes attached to sectors and brushes on neutralizing rod; sectors between stationary plates or on their external surface; in the latter case the sectors are provided with metal points which discharge on the surface of the revolving plates.

Embodying the distinctive characteristics of the Toepler type is a machine in which a material which resists the destructive effects of high speeds is substituted for the more fragile glass used in all other machines. This material may be either mica or fiber. Figure 109 represents a machine which may attain a speed of two thousand revolutions per minute, manufactured by the R. V. Wagner Company, of Chicago. In this machine two glass plates with paper sectors and tin foil between them are joined with clasps, the tin foil being connected by a wire with combs placed on the opposite ends of an insulated rubber arm. The initial charge is produced by brushes which touch metal disks upon the front surface of the anterior plate.

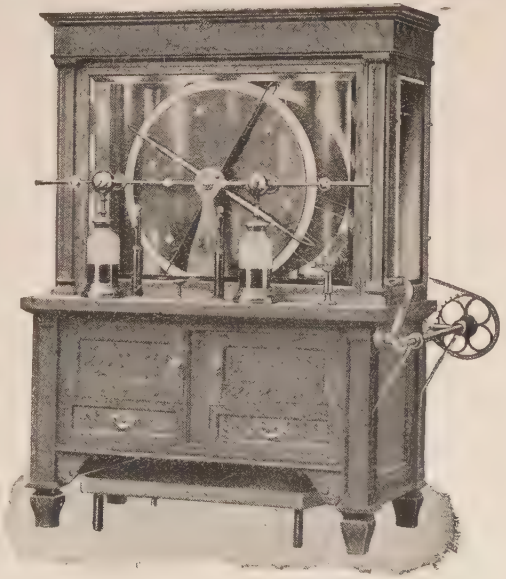
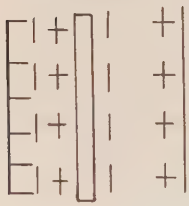


Fig. 109.

Excitation of the Sectors in Static Machines.—(*a*) In the Holtz machine the initial charge is furnished by an accessory machine, which may be a small Wimshurst or Toepler apparatus. This primes one

of the sectors and thus prepares the machine for action. Assuming that the right-hand sector is positively charged, negative electricity is discharged upon the internal surface of the rotating plates, the front surface becomes positive and the comb directly opposite discharges negative electricity against it. The front surface being now negative is carried to the opposite side of the machine where it subtracts positive electricity from the comb and by an inverse process renders the left hand sector negative. (*Fig.* 110.) Modifications of either the Holtz or Toepler machines, which dispense with disks and brushes, get their exciting charge as above described.

FIG. 110



(*b*) In the Toepler machine the initial charge is obtained by the friction of brushes upon the surface or surfaces of the revolving plates.

Assuming that the sector on the right side (*Fig.* 111) has received a positive charge from the friction of the brush connected with it, we represent disk 1 as about to pass under the comb of the neutralizing rod C. In its unexcited condition it contains electricities of both signs. Under the influence of the excited sector its positive electricity is repelled to the neutralizing rod, and when it advances to the position marked 2, it has a free minus charge. When it has advanced to position 3 it has just passed the comb and given its minus charge to the sector with which it is connected. Having now given up its minus charge, it is practically neutral, but being in front of a minus

sector, which by constant additions is becoming more and more strongly charged with negative electricity, it will have minus electricity now repelled from it, when it reaches position 4 which is about to pass under the comb of the neutralizing rod C. When it reaches position 5 it has a free positive charge which it gives to A as it passes under it.

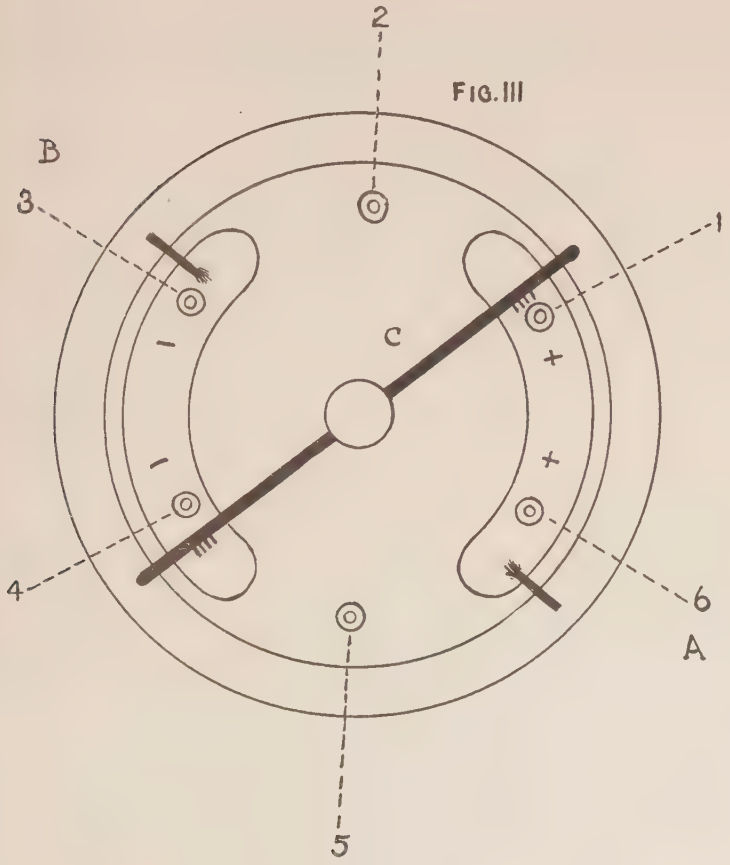


FIG. III

Charging of the Prime Conductors. By consulting Figure 112 it will be noted that the neutralizing rod is in front of the end of the sector on the right, which is positive. This sector will therefore attract negative electricity upon the rotating plate. When the rotating plate has come under the combs connected with the prime conductor on the left side, it is in front of the minus sector. These combs were originally neutral, but now will discharge positive electricity upon the rotating plate. When the revolving plate

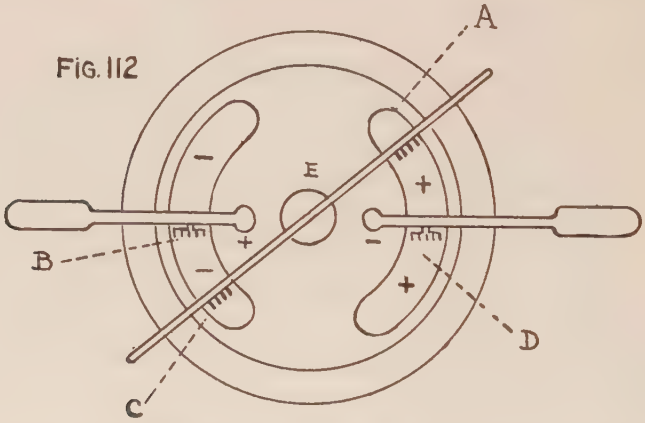


Fig. 112

which is still negative passes under the combs of the neutralizing rod E, positive electricity is discharged upon the plate, and when it reaches the combs of the prime conductor on the right, the latter will discharge negative electricity upon the revolving plate. While the balls of the prime conductors are originally of opposite sign from the corresponding combs, following the law of electro-static induction, yet they quickly acquire the same charge, and the balls deliver elec-

tricity of the same sign as the combs with which they are connected.

Grounding. A static machine may be grounded by carrying a wire from either pole to a gas fixture, water pipe, or other metallic connection, or to an iron rod fixed in moist earth. For this purpose a wire may be carried along the upper border of the cabinet with a free end which can be attached to either pole as desired, the other end being connected as above described. Some operators permanently ground their machines by connecting the forward feet with a wire conductor which is carried to the ground, as already described.

Advantage of Grounding. When an electrode is grounded it has the same potential as the operator, who may now touch the side of the machine with which the electrode is connected without getting a spark. This advantage is particularly manifest in giving spark treatments. The operator may give his whole attention to the patient without fear of directing the spark to himself.

Care of the Machine. The static medium machine has been called "capricious," "uncertain," "unreliable." It is safe to say that when a static machine fails to develop a charge or generate up to its ordinary volume, some adequate reason exists for this condition. Nothing is more unscientific than to assume some other relation than cause and effect in the behavior of a static machine. If it fails to charge, a cause exists somewhere, and the machine is not outside the sphere of natural law. Indeed caprice

has no place in the scheme of nature, and to assume that it exists is to revert to the attitude of the savage in his interpretation of natural phenomena.

The first thing to remember in the operation of a static machine is that it generates exceedingly small currents. If, therefore, the plates of a machine are covered with dust or moisture, the initial charge may not be obtained, because the insulation of opposite sides of the plates is destroyed by the deposit of conducting materials upon their surfaces or upon the arms supporting the charging and collecting combs. The obvious necessity, therefore, is to keep the machine free from dust and as free as possible from moisture. How to do this is explained in the printed material which the manufacturer or his agent supplies to his customer, and as it is the purpose of this exposition to explain principles rather than to supply information readily accessible elsewhere, the latter will not be introduced here.

We may say, however, that in the Wagner machine the problem of dust and moisture has been largely solved. It is a fact which all operators have observed that an enclosed machine which has been in operation for a long time will generate better if the enclosed air is driven out and a fresh supply introduced. This would indicate that certain gases are generated by the electric discharges inside the cabinet, which tend after a time to resist the generation of electricity. These gases are produced by the union of free atmospheric nitrogen and oxygen or by the union of atmospheric nitrogen with the oxygen of the

water molecule. There is some obscurity as to which of the nitrogen oxides are produced by high potential discharges. Of the five nitrogen compounds of oxygen, one or more may be generated along with a certain percentage of nitrous and nitric acids formed by union of $N_2 O_3$ (nitrogen trioxide) and $N_2 O_5$ (nitrogen pentoxide) with aqueous vapor. Thus $N_2O_3 + H_2O = 2HNO_2$ (nitrous acid); $N_2 O_5 + H_2O = 2H NO_3$ (nitric acid). It is certain that these gases are corrosive in their action, attacking the metal parts of the machinery to some extent and weakening and ultimately destroying the shellac commonly used to cover the plates. It is found practical to supply the Wagner machine with dust-proof ventilators, which permit the escape of noxious gases which interfere with the generation of electricity, and form deposits upon the surface of the plates and insulated arms. The free communication of the interior of these machines with the exterior atmosphere, and the consequent introduction of moisture, does not ordinarily interfere with the excitation of the sectors, since in the type used for therapeutic purposes there are but two revolving plates. Now, where there are but two revolving plates there are only two surfaces from which leakages can occur as against four, six, eight, or ten surfaces in machines employing glass revolving plates which generate little if any more current. Apparently the question of eliminating moisture becomes of more consequence as the number of revolving plates increases, but is of relatively less consequence in high-speed machines employing fewer revolving plates.

Amperage, Voltage, Frequency. These are considerations of the utmost importance in connection with the discharges of static machines. In spite of this fact, they have not, as yet, been adequately determined. The Committee on Current Classification and Nomenclature, appointed in 1901 by the American Electro-Therapeutic Association, consisting of eminent electrical engineers, have made the most notable contribution to the solution of these problems; yet their work leaves much to be desired. Such original work as was done by that Committee had relation entirely to the determination of amperage and efficiency. With the latter the physician has slight concern, as power is not a consideration of much consequence. The discussion of frequency recited certain formulæ which were already well understood. The question of voltage was not raised, as if that was a consideration of little moment to the physician, and the factors which determine potential were not stated. In the text-books which aim to throw some light upon static machines we are frequently told that amperage depends upon the number of revolving plates, and voltage upon the diameter. This is a manifestly inadequate *dictum*, since amperage depends also upon the diameter, and voltage upon the number of revolving plates. So long as writers of text-books are satisfied with such inadequate and partially correct propositions, the static machine will continue in the future, as it has been in the past, to be *terra incognita*.

Amperage.— In determining the amperage of

static machines the committee above referred to enumerated the following factors: (*a*) number of rotating plates; (*b*) length of collecting combs; (*c*) distance of center of collecting combs from the axis of rotation, and (*d*) speed of rotation of plates; and the conclusions which they formulated are that the current strength is directly proportional, (*a*) to the speed of rotation of the plates; (*b*) to the length of the collecting combs; (*c*) to the distance of the centers of the collecting combs from the axis of rotation of the plates, and (*d*) to the number of rotating plates.

As an initial step in the analysis of current strength, these conclusions are valuable. But it would seem that there are still other factors that were overlooked; namely, (*a*) the size of the inductors upon the stationary plates, (*b*) the distance between stationary and rotating plates, and (*c*) the characteristics of the dielectric employed. It is well, also, in passing to call attention to the conclusion of the committee as to the relation of speed of revolving plates to output. It is unequivocally stated that output is directly proportional to the speed of the revolving plate. Therefore it would seem undesirable to multiply revolving plates where an equal amperage can be obtained by increasing the speed of revolution. Where power is cheap, peripheral speed would seem to be open to no objection, especially as it tends toward simplicity, which is the ideal of mechanical construction. Working upon this basis manufacturers have put upon the market machines operating

a few revolving plates, which furnish an output equal to those of earlier design operating a considerably larger number.

Voltage.— It is a matter of observation that a static machine running at a low speed generates less potential than if it runs at a higher speed; in other words, it can bridge a larger spark gap running at a high speed than when it runs at a low speed.

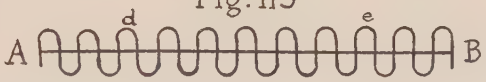
In like manner it will be observed that if any one of the factors above noted as entering into the production of amperage be altered, there is a corresponding change in the voltage. It would seem fair then to say, that to a very considerable extent the same factors that enter into the production of amperage control the potential of static discharges, and that therefore the *dictum* that amperage depends upon one set of conditions and voltage upon another seems to be without foundation.

Frequency.— By frequency is meant oscillation, and oscillation is characteristic of alternating currents. The current produced by a static machine is a direct current. It is not oscillating in a true sense, unless its Leyden jars are introduced into the circuit, and an induced current is derived from the outside armatures. Where, however, there are introduced into its external circuit bodies which are capable of acting as capacities, like the armature of a Leyden jar, we may get oscillations superimposed upon the direct current. This may take place if the prime conductors consist of large balls terminating the sliding rods of the static machine, and the direct current

thus generated may be graphically displayed thus (*Fig.* 113), in which A B represents the direct current and D E the superimposed curves produced by the oscillations of the current due to the capacities interposed in the circuit.

Reversibility. It is found that a static machine is capable of acting as a motor as well as a generator.

Fig. 113



Thus if the opposite poles of two static machines be joined and the first be set in motion, the combs of the second will light up and the plates will revolve, but in a direction opposite to their usual motion. There is, of course, a considerable loss of efficiency owing largely to leakage by conductors and uninsulated surfaces.

CHAPTER XIII

STATIC ADMINISTRATIONS

Discharges from a static machine may be grouped under three heads, viz: (1) convective, (2) disruptive; and (3) conductive.

(1) Under the first group are included (*a*) static insulation, positive or negative; (*b*) the static breeze; (*c*) the static spray, each of which is administered with the patient placed upon an insulated platform; (*d*) brush discharges; and (*e*) vacuum tube discharges.

(2) Under disruptive charges are grouped the various sparks, *viz.* (*a*) direct; (*b*) indirect; (*c*) friction, and (*d*) Leyden jar.

(3) Conductive discharges comprise (*a*) the static induced current and (*b*) the wave current.

While the historical order of development of static treatment would require a consideration of disruptive discharges first, inasmuch as these were the first static modalities discovered, yet, since convective discharges are to be preferred as a means of initiating the patient into the static method of treatment, because, when properly administered, they are devoid of disturbing effects upon the mind, we shall give our attention first to:

I. Convective Discharges.— (*a*) *Static Insulation.* The patient is placed upon the insulated platform, and connected with either the positive or the negative pole, the indifferent pole being grounded. The positive pole is stimulating, the negative sedative, and the one or the other should be chosen according to the effect desired. The prime conductors are drawn apart beyond sparking distance. (*Fig.* 114.) While the patient is in this position, the method may be modified by placing the prime conductors near

Fig. 114.

enough to permit an intermittent spark. This is called *interrupted electrification*, but is markedly inferior to the wave current, to be later described.

(*b*) *Static Breeze.* This is strictly a modification of static insulation already described. The patient sits upon the insulated platform, and is connected with either the positive or the negative pole, the indifferent pole being attached to a standard supporting a metallic crown placed from one to two feet above the head. (*Fig.* 115.)

(*c*) *Static Spray.* If instead of using the crown as above described a point be employed either attached to the standard or to an insulated handle in the hand of the operator or patient, the spray is obtained. This permits more careful localization of the static discharge and a nearer approximation to the surface of the body. (*Fig.* 116.) To strengthen the effect, the spray should be thrown upon a thick woolen or silk garment. Where the garments of the patient are not of suitable material, a square yard of silk or woolen material may be thrown over the part to be treated. To increase the local effect, an electrode having several points may be employed. (*Fig.* 117.)

Multiple Point Terminals.— Figure 118 represents a device for slipping over the balls on the sliding rods. The multiple terminals enable the operator to bring the point electrode, in administering the static spray, nearer to the patient, and thus secure greater localization of the discharge. Moreover, they may be brought together without producing a shock to the patient, and further enable the operator to

Fig. 115.

Fig. 116.

regulate the current readily, by adjusting the distance between the terminals without altering the speed of the machine. The indirect method of administering both the breeze and the spray may be employed. This consists in grounding the indifferent pole, and connecting an insulated cord with a water pipe or other fixture at one end, and the standard or handle of the electrode in use at the other end.

(*d*) *Brush Discharge.* This occurs when the patient is placed as already described and the dis-

charge from the electrode is made through a resisting material like wood. (*Fig.* 119.) The wood selected should be preferably the white portion of soft maple or white wood or holly. The brush discharge varies greatly with the condition of the atmosphere as to

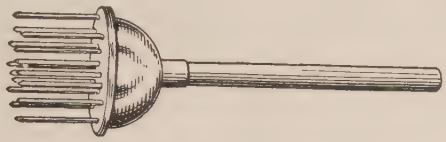


Fig. 117.

temperature and humidity, being stronger where the temperature and humidity are high. Over a wet surface the effect is slight. Cotton or linen impairs the activity of the discharge. Strong effects are produced by using a silk or woolen material above the

Fig. 118.

part to be treated. Here also the discharges may be made indirectly through the indifferent pole which has been grounded, the patient being connected directly with the generator.

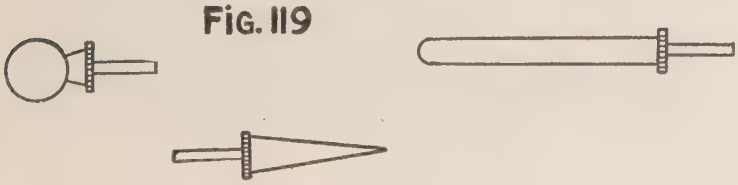


Fig. 120.

(*e*) *Vacuum Tube Discharges.* These discharges are administered by means of glass vacuum electrodes placed in the socket of an insulated handle, and attached to the negative side of the machine, the positive pole being grounded. Unlike the previously described modalities, this does not require the patient to be insulated. (*Fig.* 120.) At the beginning of the treatment the sliding rods are together, and gradually separated until the required strength is obtained.

A muffler (*Fig.* 121) is a useful addition to a static machine, both because it reduces the noise of the spark between the prime conductors, and also because a fine thread on one of the small sliding rods enables the operator carefully to adjust the strength of the current.

Glass vacuum electrodes, of which several varieties are shown in the accompanying cuts (*Fig.* 122), together with insulated handles, light up with varying colors according to the degree of exhaustion and the strength of the current, and deliver discharges of differing character according as they are

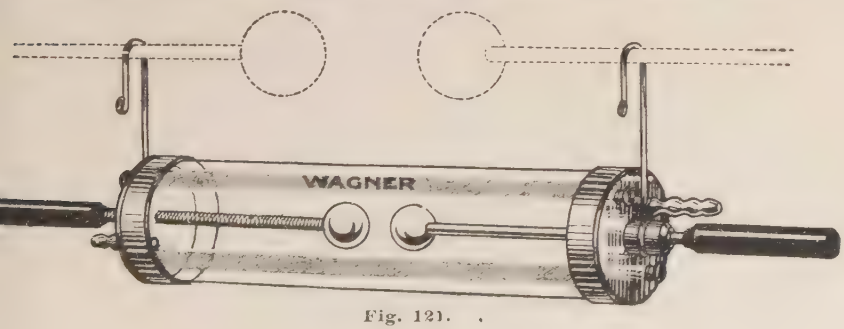


Fig. 121.

produced by static machines or coils. There are also marked variations in discharges furnished by different static machines. Because coils employ a larger amperage, the discharges produced from this source are usually more marked in heat and chemical effects. The static machine produces more marked vibratory effects, which are noticeable in the

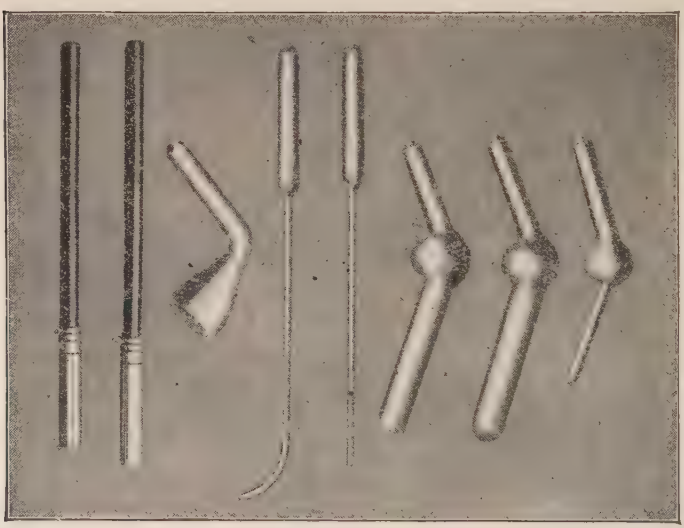


Fig. 122.

contractions in muscular tissue. Where a greater chemical effect and higher frequency are desired, the coil would seem to possess advantages. Where the aim is to induce muscular contractions, the static machine would have the preference.

II. Disruptive Discharges. — (*a*) *Direct Sparks.* To obtain these the patient is placed upon

the insulated platform, care being taken that it is two or more feet from the machine. The patient should be connected with the positive side of the machine. The ball electrode in the hand of the operator is con-

Fig. 122A

nected with the negative side. The sliding rods are widely separated. After these steps have been successively taken the machine should be started. (*Fig.* 122A.) This is a painful treatment and should not be employed except in cases of marked anesthesia, or where profound effects are desired, or when owing to atmospheric conditions the indirect spark, next to be described, is not sufficiently powerful.

The positive spark should be employed in preference to the negative, because the former is less likely to split and divide. The length of the spark may be controlled by (1) altering the speed of the revolving plates; (2) by altering the distance between the sliding rods; (3) by the operator's placing one foot upon the platform, and thus drawing off a part of the charge from the patient; or (4) by connecting the platform with the conducting cord or rod instead of with the patient directly.

In administering the spark a ball electrode is used, and where the ball is larger the spark is thicker. The operator should give the treatment with a wrist motion, which is easily acquired, or by a swinging motion of the arm. Where the garments of the patient are wet, or for other reasons the sparks are abortive, a woolen cloth or newspaper may be placed over the part treated.

(*b*) *Indirect Sparks.* This treatment differs from the preceding only in manner of attachment of the cord connected with the spark electrode. The machine being grounded upon the negative side, connection is made by the operator's cord with a water

pipe or other metal fixture, the patient being attached to the positive side of the machine by means of a rod, cord, or chain. Indirect sparks are milder than direct sparks, and for most cases where spark treatment is applicable, should be preferred.

(*c*) *Friction Sparks.* This treatment differs from the indirect spark treatment only in the manner of using the ball electrode. Instead of holding it at a distance from the patient it is placed upon the surface to be treated, or upon the superimposed clothes, and quickly moved backward and forward. If the atmospheric conditions interfere with the efficiency of the treatment, the ball electrode may be directly connected with the machine.

(*d*) *Leyden Jar Sparks.* The arrangements do not differ from those required for direct spark treatment, except that the Leyden jars are introduced into the circuit. This treatment should not be employed except under very unusual conditions determined by the mental attitude of the patient.

(3) Conductive Discharges.— (*a*) *The Static Induced Current.* This was first introduced to the profession by Dr. William J. Morton, in 1881. The manner in which the discharges are excited are graphically represented in Figure 123, where *a* represents the rods connecting the prime conductors with the internal armatures of the Leyden jar, *b* represents the external armatures, *c* the conductors, and *d* the electrodes.

For this treatment the patient is seated upon an insulated platform, though insulation, as in Figure

123, is not necessary. The conducting cords are attached to binding posts connected with the external armatures of the Leyden jars. The muffler is preferably used, the rods being brought together, and the larger sliding rods being slightly separated. The machine is then slowly started. The electrodes are applied to the areas to be treated and the muffler rods gradually drawn apart. A very small gap

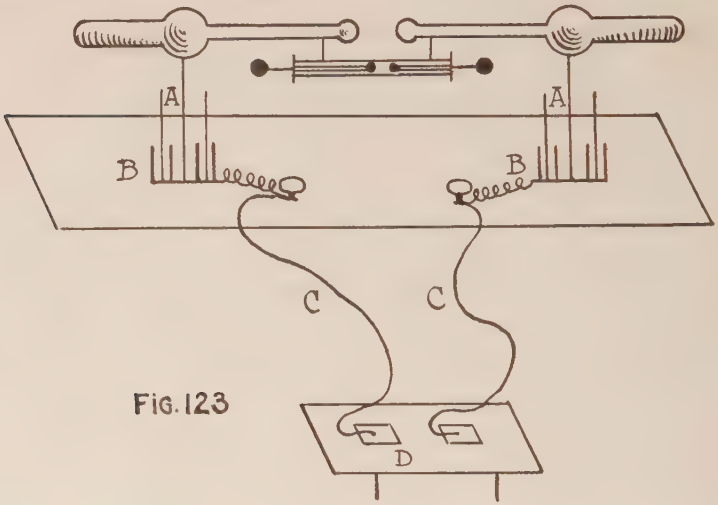


Fig. 123

suffices to produce powerful effects upon the muscles of the patient. Contractions are powerful, and with too large a spark gap exceedingly painful. The discharge, however, can readily be controlled by use of the muffler. (*Fig.* 124.)

Transformers. The relations between voltage and amperage may be altered by introducing a coarse copper wire of fifteen to twenty turns in series with

Fig. 144.

the external armatures of the Leyden jars, and attaching conductors to the terminals of the solenoid. Here there is a downward transformation of the voltage and an increase in the amperage; or the voltage may be raised if it is deemed desirable, and the amperage lowered by introducing into the circuit between the

external armatures a coarse wire solenoid around which and insulated from which is another solenoid of finer wire. Such a coil is called a step-up transformer and gives painless currents.

The static induced current historically considered was the forerunner of those currents of rapid oscillation to which the name high frequency has been applied, and which have, in recent years, been the subject of much study.

(*b*) *The Wave Current.* To this the French give the name " Franklinization Hertzienne," because the circuit is completed by Hertzian waves emanating from the person of the patient. It is a mono-polar current. Here the patient is placed on the insulated platform and is connected with the positive side of the machine by means of an electrode and conducting cord. The negative pole is grounded. The sliding rods are together and are gradually drawn apart until the desired effect is obtained. The Leyden jars are introduced into the circuit and the machine is run at low speed. (*Fig.* 125.)

In administering this form of treatment special care must be given to the insulation of the patient, the insulating platform being not less than three feet from the machine, and the conducting cord held taut, to avoid leakage to surrounding objects. The electrodes should be placed in close apposition to the part to be treated, to avoid the disagreeable sensations resulting from spark gaps. This may be effected by the use of a bandage or by pressure of the electrode against a cushion or similar object.

Fig. 125.

The size of the electrode used is a matter of great importance. This will depend upon a variety of considerations, *viz:* the extent and nature of the disease treated, the temperament of the patient, the character of the insulation, the condition of the atmosphere, and the capacity of the machine. An electrode having a surface of twenty-five inches square is ample for a spark gap of four or five inches. The material may be block tin or tin foil, such as is used to protect patients from the untoward effects of the X-ray.

The positive pole is selected for application to the patient because the number of oscillations from the positive pole is greater than from the negative. It has also been observed that the negative pole is more irritating. The same factors will govern the length of the spark gap as were enumerated above in discussing the size of electrodes to be employed.

CHAPTER XIV

CLASSIFICATION OF CURRENTS. HIGH FREQUENCY CURRENTS

Currents may be divided into two general classes; *viz:* I, Direct Currents, and II, Alternating Currents.

I. Direct Currents. — These are unidirectional and may be graphically represented, thus: (*Fig.* 126.) The characteristic of these currents is that they do not change their polarity, and though the curve may be broken as at A, it always continues above the line.

To this class belong, (*a*) *Continuous currents*, which never have a zero value, though they may vary in potential, thus: (*Fig.* 127.) (*b*) Constant *currents*, which do not vary their potential, thus: (Fig. 128), and (*c*) *Pulsatory currents*, which vary their potential in repeated cycles, thus: (*Fig* 129.) These may be of varied types, of which the above graphic representations give a generalized picture.

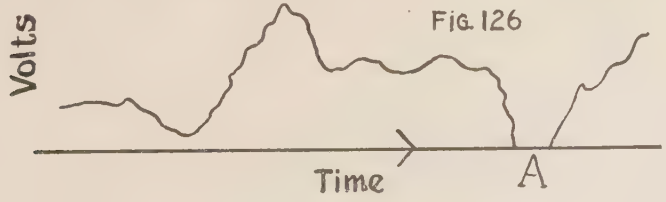


Fig. 126

II. Alternating Currents.— These are currents which periodically flow in opposite directions, and in both directions for the same length of time, thus (*Fig.* 130.) When the current has passed from

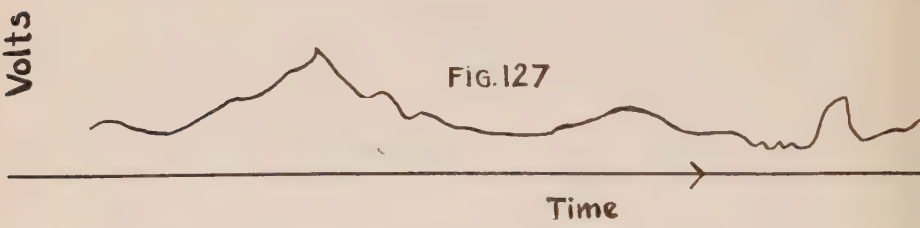


Fig. 127

zero in one direction to its maximum and then to zero again, and from zero to its maximum in the other direction and back to zero, it is said to have completed one cycle or two alternations. The number of cycles

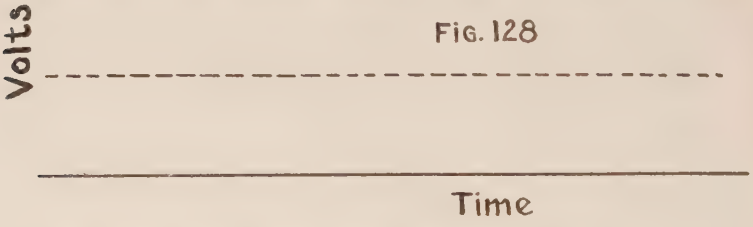


Fig. 128

in one second constitutes the frequency of the current. When such a current has a pure wave form, it is called a sine-wave or sinusoidal current. The curve

Fig. 129

may vary widely from a pure sinusoidal curve and yet be a true type of an alternating current, thus: (*Fig.* 131.) To the type of alternating currents, though not strictly a subdivision of such currents, since they

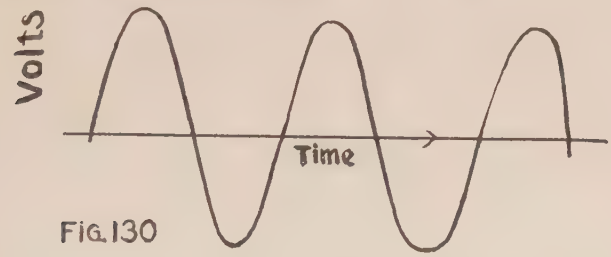


FIG. 130

are not symmetrical are, (*a*) *Oscillatory currents*, of which Figure 132 is a graphic representation. These currents flow periodically in opposite directions, but

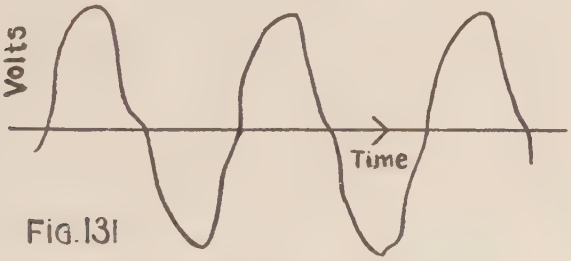


FIG. 131

not necessarily for the same length of time. The maximum values of successive waves change in a regular order.

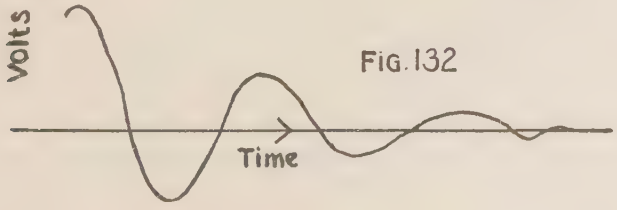


FIG. 132

(*b*) *Unsymmetrical Wave Currents.* Here the currents flow in opposite directions, but do not attain the same maximum in both directions, thus: (*Fig.* 133.) Of the currents above graphically displayed, we have already discussed the direct, as illustrated by primary and secondary batteries and the direct current of the commercial mains; pulsating currents, as produced by rectifiers; the asymmetrical wave current, as illustrated by the induction coil; the alternating current, as illustrated by the alternating current motor and the alternating current of the commercial mains; and the sinusoidal wave current said to be produced by the

Fig. 133

Wappler Automatic Exerciser, No. 2. (*Chap. IX, Fig.* 76.)

There yet remain to be described oscillatory currents, which introduce us at once into the interesting field of so-called high frequency currents.

It was Joseph Henry, of the Smithsonian Institute, Washington, D.C., who made the discovery that the discharges of a Leyden jar produced oscillatory currents. Lord Kelvin later correctly stated the theory explaining these phenomena, and Feddersen, Helmholtz, and Schiller have experimentally substantiated it. With the further development of this

discovery one links the names of Hertz, Maxwell, Lodge, D'Arsonval, Tesla, Elihu Thompson, and others.

Since there is considerable confusion as to how oscillatory currents are produced, it may be well to pause for a moment in order to obtain, if possible, a clearer conception of the factors which enter into their production.

An analogy will serve to furnish a mental picture of what takes place when an oscillatory current is generated. If a steel spring is held in a perpendicular position between the thumb and forefinger, and drawn back by the fingers of the other hand, it will rebound, passing beyond the perpendicular position to almost the same position on the other side. These movements will continue until the spring gradually assumes a position of rest. This furnishes a picture of an oscillatory wave. Three factors determine the rapidity of its motion, *viz:* (*a*) the flexibility of the spring, (*b*) the load which it carries, and (*c*) the resistance of the medium through which its excursions travel. It can readily be perceived that if the spring is lengthened it will vibrate less rapidly; so also if a weight is attached to its upper end, or if the viscosity of the medium in which its movements take place is increased. If now we translate these terms into electrical language, we shall find that flexibility corresponds to capacity, the load or inertia corresponds to self-induction or inductance, and the viscosity of the medium corresponds to resistance. The unit of capacity is the farad, the unit of inductance is

the henry, and the unit of resistance is the ohm. Thus it has been mathematically demonstrated that currents are oscillatory in character when unity, divided by the product of the capacity and inductance, is greater than the square of the resistance divided by four times the square of the inductance, or $\frac{1}{\text{capacity} \times \text{inductance}} > \frac{\text{resistance}^2}{4\ \text{inductance}^2}$

Recurring now to the analogy of the steel spring, it can readily be perceived that by suitably varying the factors of flexibility, load, and the viscosity of the medium, the oscillations of the spring may be entirely damped out, and that the spring when pulled back might simply return by a slow motion to its original position and remain there.

High frequency currents may be defined to be currents of high potential and enormous frequency of oscillation, frequently obtaining a speed of one hundred million or more per second.

Comparison of Frequencies. A comparison of frequencies will serve to assist the student in relating high frequency currents to those already studied and to other well-known physical phenomena. The usual rate of alternation in the commercial alternating currents is sixty cycles, or one hundred and twenty alternations per second. (*Chap. VI.*) An ordinary induction coil with hammer break may furnish upwards of one hundred interruptions or two hundred alternations per second. A Rhumkorff coil with Wehnelt electrolytic interrupter may produce upwards of one thousand interruptions or two thousand alternations per second. By sending an alternating current through a

transformer in series with a condenser, the alternations may be increased to a million or more per second. When, however, these alternations are compared with the alternations or waves necessary to affect the retina and produce the perception of color, it is seen that, relatively, the former are still of low frequency, inasmuch as the latter range between four hundred and seven hundred billions per second. We are thus taught that the question of frequency is wholly a relative one, since high frequency in one department of physics is low frequency in another.

It is important to remember that the agency in exciting the rapid oscillations to which the name high frequency is applied is the condenser, of which a description was given in Chapter III on the physics of the induced current.

Static Induced Current. The first high frequency current for therapeutic use was introduced to the profession by Dr. William J. Morton, in 1881, and called the static induced current. Figure 134,

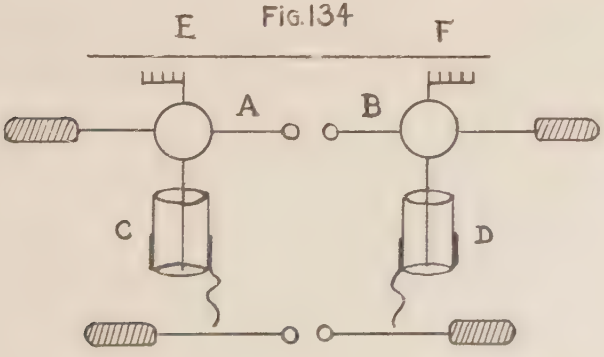


Fig. 134

which illustrates this current, fully explains all that is fundamental in a high frequency current. The separation of the sliding rods A B permits the current to collect upon the terminals, where, after it has acquired sufficient tension to overcome the resistance of the air, it leaps across. This is the spark gap which figures in all high frequency apparatus. C and D are the Leyden jars which act as condensers, the inner armatures of which are connected with the

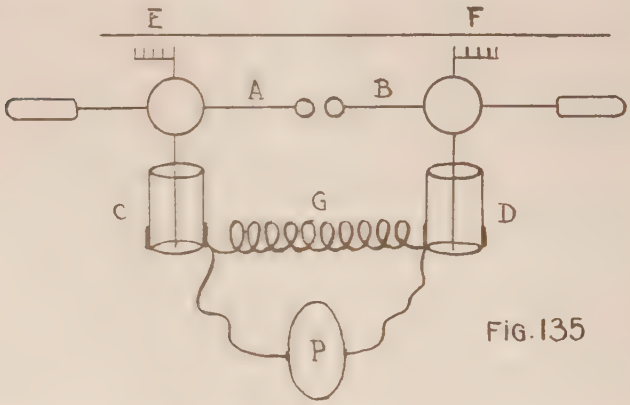


FIG. 135

collecting combs E F. The charging of these armatures induces a charge in the external armatures to which the conducting cords and electrodes are attached.

D'Arsonval's Modification. The later modification of D'Arsonval (*Fig.* 135) consists in the introduction of a solenoid as a shunt circuit. The source of the exciting currents employed by D'Arsonval and his collaborators was an induction coil instead of a static machine.

Oudin's Modification. The current produced by this arrangement is not a current of very high potential. Oudin, a pupil of D'Arsonval, therefore raised the voltage by adding a solenoid to the apparatus constructed by his master, thus: (*Fig.* 136.)

Foreign apparatus has been constructed for the most part upon the lines laid down by D'Arsonval and Oudin. American apparatus has developed a different type, founded largely upon the researches of Nikola Tesla and Elihu Thompson. In this type of apparatus the exciting current is alternating and is obtained from the commercial alternating current, or, where that is not available, from a rotary converter or alternating dynamo run by the commercial direct current. Without undertaking to show the various modifications which this apparatus may undergo to effect special purposes, Figure 137 well illustrates the various steps by which frequency and voltage may be altered in this type of construction.

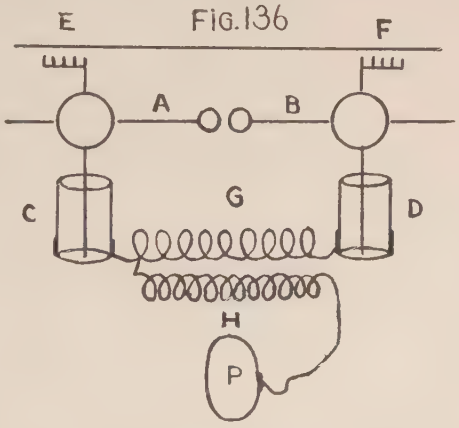


Fig. 136

The current issues from the rotary converter or alternating mains as a low voltage, low frequency current, passes into the primary B of the transformer C and is converted into a high potential current by the

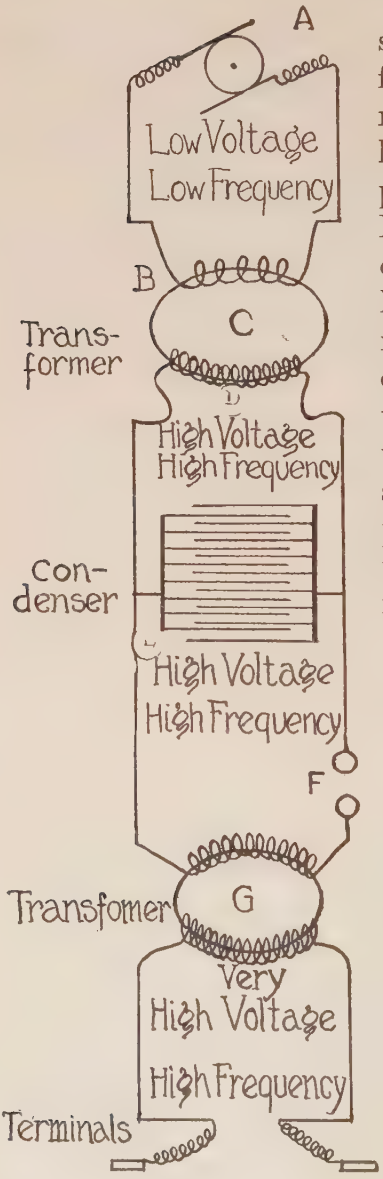


Fig. 137.

secondary D of the transformer. It is now a current of high voltage but low frequency. It next passes into the condenser E and by alternate condensations and discharges has its frequency enormously increased. The current next passes through the spark gap F, the regulation of which serves to control the potential of the current, though slight alternations in frequency may also be effected. It next passes through the primary of the transformer G and issues from the secondary as a current of very high voltage and high frequency.

In this description of the development of high frequency currents of high potential we have not paused to describe interrupters, alternating currents, transformers, and condensers, inasmuch

as they have been carefully explained in previous chapters, and any one who has carefully followed them is prepared to understand every step in the process.

Sources of Electrical Energy. If the foreign type of high frequency apparatus be employed, the source of electrical supply may be primary or secondary batteries or the direct current commercial mains, or it may be the static machine. If the American type be used, the alternating current supplies the necessary power.

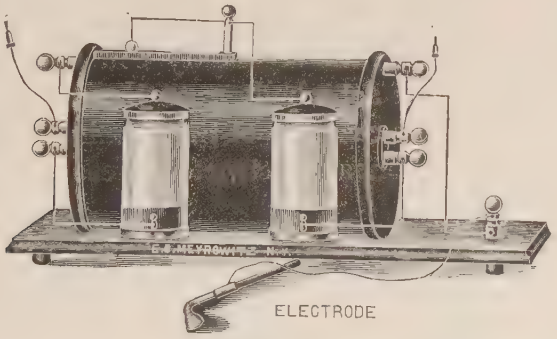


Fig. 138.

D'Arsonval Current. This is obtained from an induction coil or static machine by introducing about twenty coils of thick copper wire in shunt with the patient. Such an arrangement is in reality a step-down transformation, inasmuch as the volume of current is increased, but the potential decreased.

Oudin Resonator. In order to raise the potential one end of the D'Arsonval solenoid may be connected with a secondary winding of finer wire. For con-

venience both solenoids may be wound upon one drum, as shown in Figure 138. The free end of the secondary wire will discharge a shower of sparks when the circuit is admitted to the coil. A movable contact is provided in order that the primary or D'Arsonval solenoid may be brought into such relation with the secondary coil as to produce the greatest effect, as evinced by the effleuve or discharge from the terminal. This is the phenomenon of resonance, which will later be explained. The arrangement above described bears the name of the Oudin Resonator, in honor of its inventor. Instead of being connected with the D'Arsonval solenoid the secondary coil may be detached from it and act wholly upon the principle of induction. In this case one of the terminals may be grounded. D'Arsonval constructed a resonator upon this principle.

Figure 139 represents a complete high frequency outfit made by the E. B. Meyrowitz Co., of New York. The different components are readily recognized, *viz:* induction coil, condensers in the form of Leyden jars, drum upon which are wound the D'Arsonval solenoid and Oudin resonator. A movable contact is provided for producing the phenomenon of resonance. A hot wire milliamperemeter, an important and necessary accessory, is shown to the right.

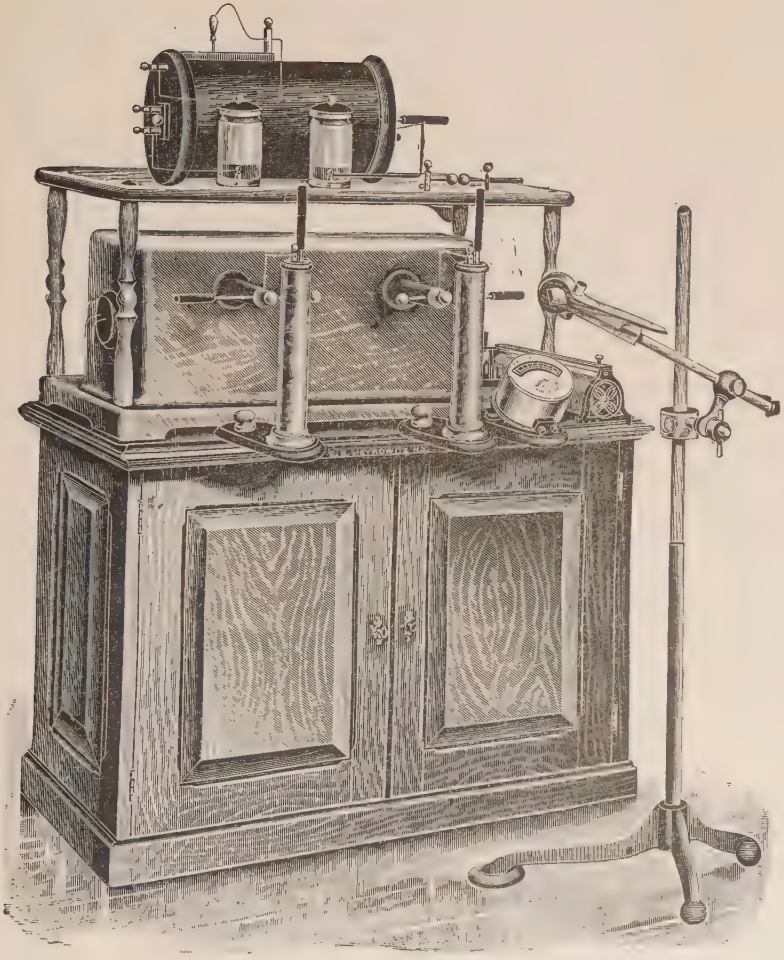


Fig. 139.

CHAPTER XV

PHYSICS OF HIGH FREQUENCY CURRENTS. METHODS OF ADMINISTRATION

The physical properties of high frequency currents may be conveniently grouped under five heads:

I. Electro-Static,
II. Dynamic,
III. Inductive,
IV. Resonance,
V. Phoresis.

(1) Electro-Static Phenomena.—Here may be noted those effects with which we have already become familiar in the study of the static machine. They are (1) luminous; (2) chemical; (3) condensatory, and (4) inductive. In general it may be said that these effects do not differ in kind from those obtained from static machines. As, however, larger currents are ordinarily furnished from high frequency apparatus than from static machines, it may readily be inferred that electrostatic phenomena are more powerful in the former than in the latter.

(1) Under *luminous effects* we note (*a*) spark discharges and (*b*) brush discharges. These effects are usually accompanied by hissing or crackling noises.

(2) Under *chemical effects* we note (*a*) the electrolytic decomposition of salts in solution, as when a spark is permitted to fall upon a blotting pad containing a saturated solution of iodide of potassium. The characteristic appearance of iodine is observed; (*b*) the production of ozone; and (*c*) the generation of nitrous and nitric compounds as evidenced by corrosive effects upon metals which are in the neighborhood of the spark. (See Chap. XII, where the chemical formulæ are presented.)

(3) *Condensatory Effects.* Examination of the Leyden jars of a static machine after it has generated a current for some time reveals a deposit of finely divided material upon the external surface. This is the now familiar effect due to discharges of high potential to which attention was first called by Sir Oliver Lodge. Where the discharges are large there is a deposit upon the walls and surrounding objects.

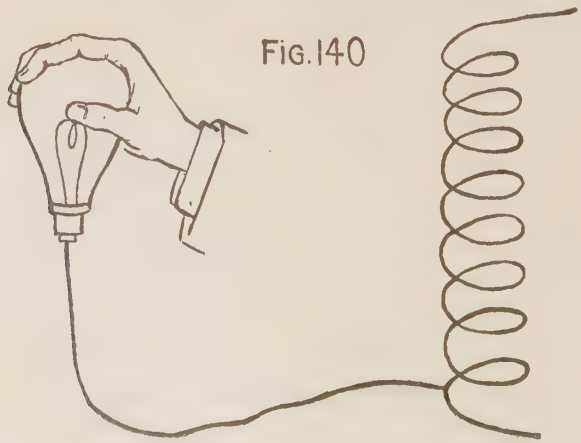
(4) *Inductive Effects.* Vacuum tubes introduced into the electro-static field are immediately illuminated, though there is no direct contact with the source of supply.

II. Dynamic Phenomena.— These are manifested by the remarkable property which high frequency currents possess of circulating in open circuit. By this is meant that, while direct currents require metallic conductors for their transmission, high frequency currents are able to dispense with such assistance. This would seem to controvert our experience as to the behavior of insulators and conductors. There is, however, only an apparent contradiction of

what experience has already taught us. There are, after all, no open circuits, and currents of high voltage and frequency are able, by so-called "displacement currents," to return upon themselves without the assistance of metallic conductors. Thus where a space intervenes between a terminal and a generator, the discharge is transmitted by means of stresses upon the incompressible ether, just as pressure upon a diaphragm at one end of a tube containing water is felt upon a similar diaphragm at the other end.

Thus if an incandescent lamp is held in the hand by the glass bulb, and allowed to touch a terminal of a high frequency apparatus by its metallic base, it will immediately light up. To explain this effect we must assume that the current passes through the lamp and body as a conductive current and through the ether as a displacement current. (*Fig.* 140.)

III. Inductive Phenomena.— From our study of the induction coil we have learned that an induced current is set up in a coil which is contiguous to, but



not connected with, another coil. The potential of the currents generated in the former is proportional to the rate of variation of the magnetic flux; that is to say, to the frequency of the inducing current. Thus, one may produce the same effect by a current of high frequency and low tension as by a current of low frequency and high tension. It is readily perceived, for example, that a current of two amperes with a frequency of fifty thousand in one turn of wire would produce the same effect as a current of ten amperes with a frequency of one hundred in one hundred turns of the same wire. Therefore, if the frequency is very high the inductive effect will be powerful, even though the other factors are very low.

This effect is easily illustrated by hanging an incandescent lamp upon a coil of the auto-conduction cage. (See page 210.) The lamp instantly lights up, or, again, if a coil of well-insulated wire be wound upon a glass core, and its terminals connected with an incandescent lamp, and the coil with its lamp put inside of a solenoid carrying a high frequency current, the lamp will be brilliantly illuminated by the inductive action of the solenoid upon the enclosed helix.

IV. Resonance Phenomena.— These are inductive phenomena in which the usual effect of induction is enhanced by a proper adjustment of capacity and inductance in contiguous or connected solenoids.

It is usual to furnish an analogy by reference to well-known acoustic phenomena. Every one is familiar with the fact that a note struck upon a musical instrument will produce a so-called sympathetic vibra-

tion upon a wire in an adjacent piano tuned to produce the same note.

A tuning fork set into vibration will set up a similar vibration in an adjacent tuning fork tuned to the same pitch. It will also impart its vibration to a column of air in an organ pipe which has been properly adjusted to its own rate of vibration. If now we should translate this electrical language into acoustical language, we shall find that capacity corresponds to amplitude of vibration or intensity, inductance to rapidity of vibration or pitch, and resistance to modifications in the transmitting medium. These analogies enable us to understand how, when the factors of capacity, self-inductance, and resistance are properly adjusted in contiguous solenoids, the phenomena of sympathetic vibration or resonance will take place. Thus in an Oudin resonator it is found experimentally, that, where the primary and secondary solenoids are brought into proper relation by means of the regulating device, a heavy shower of sparks is thrown off at the terminal of the resonator. If the solenoids are joined at any other points, the effleuve is greatly decreased or entirely disappears.

V. Phoresis.— Recent studies tend to show that high frequency currents are capable of conveying various medicaments into the tissues. These have later been detected by chemical analysis in the excreta. Apparently both elements characterizing phoresis, that is to say, a physical transfer of fluid and an electrolytic decomposition of molecules are concerned in this process. We have already seen that a high

tension spark can decompose iodide of potassium, and frequent experiment has shown that fluids are carried through animal membranes by the mechanical pressure of high frequency currents.

METHODS OP ADMINISTERING HIGH FREQUENCY CURRENTS

These are:

I. Direct Application,

II. Auto-Conduction,

III. Auto-Condensation,

IV. Effleuvation.

I. Direct Application.— This method is similar to that which we have already studied in our analysis of direct and induced currents. The patient is connected with the solenoid at two points. Where the electrodes are stationary, the application is said to be *stabile*, where one or both are moved, it is said to be *labile*. Figure 141 illustrates this method of application, *a* representing the solenoid, *b* the milliamperemeter, and *c* the patient. When the electrodes are applied closely to the skin, there is little or no discomfort. For this purpose the electrodes may be covered with a material which absorbs water, like spongiopiline, chamois, or cotton. If pain is felt it is due to minute spark gaps caused by

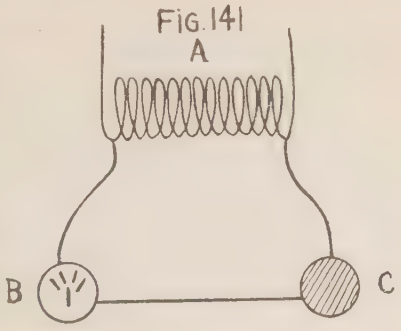


Fig. 141

imperfect bridging of the spark gap, since, as we have already learned, high frequency currents are without sensory effects when there is close apposition of the electrode to the body. When the operator prefers, he may adapt electrodes of block tin to the body and permit the patient to recline upon a couch during the administration.

II. Auto-Conduction.— Here the patient is placed inside of a large coil of stout copper wire which the high frequency current is allowed to traverse. This solenoid may be seven feet in length and from three to four in diameter, and may consist of from eighteen to twenty coils. It may be constructed for use in the vertical or horizontal position. In the former case it may

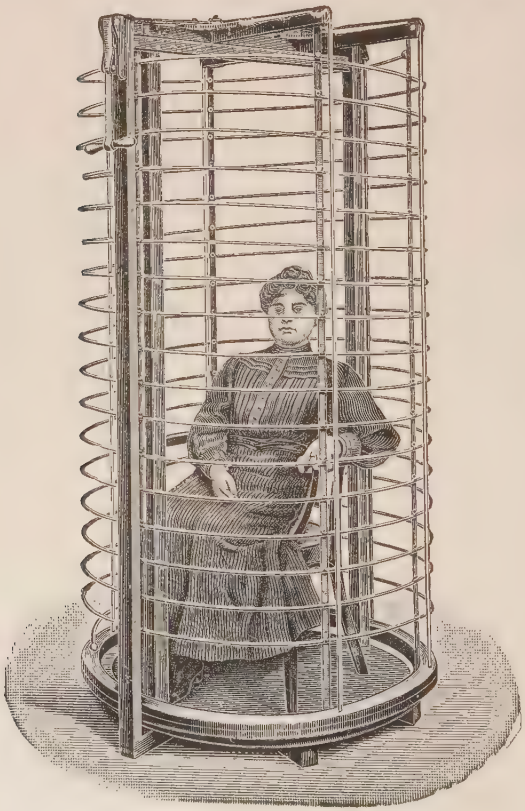


Fig. 142.

be so made that the spirals are connected by silk tapes or cords, and, the cage being suspended from the ceiling, may be drawn up like a Venetian blind when not in use. (*Fig.* 142.) If horizontal, it may be so constructed that the couch supported on rollers may be drawn out for the reception of the patient.

The effects produced by this arrangement are inductive, the body being immersed in a powerful electro-magnetic field which plays over its surface and penetrates deeply into the underlying tissues. This may be readily shown by introducing the hand between the spirals of the cage near the body of the patient, when a shower of fine sparks may be perceived bridging the gap. Again if the patient so holds an incandescent lamp that a terminal touches each hand, it will light up by means of the induced current which is formed in the circuit.

III. Auto-Condensation.— By this method marked effects are produced which are similar to those obtained by auto-conduction. The method, however, is different. This consists in making the patient one armature of a condenser, a piece of metal as of zinc or copper constituting the other armature, and a cushion of felt or rubber the dielectric. Such an arrangement may conveniently take the form of a couch. (*Fig.* 143.) The patient may thus receive a current of upwards of one thousand milliamperes. Sparks may readily be drawn from the body of the patient and an ordinary Geissler tube may be illuminated by being brought in contact with, or at a distance of a foot or more, from the patient. Some-

times a slight sensation as of warmth or prickling is produced in the patient.

IV. Effleuvation.— This method is illustrated by placing the patient under a crown somewhat similar to that used with the static machine, or a disk provided with a number of points. By suitably adjusting the distance a violet discharge will descend upon the head of the patient, producing a feeling of warmth, which changes to prickling or stinging sensa-

Fig. 143.

tions if the current is increased, or the patient brought nearer the point of discharge. It is customary to derive the effleuve above described from the terminals of the Oudin resonator or Tesla coil. The discharge is accompanied by the characteristic odor attending high frequency discharges, which imparts itself to the hair, especially, and in a less degree to the skin.

The effleuve may likewise be obtained from glass vacuum tubes which have already been described.

(*Chap. XIII.*) These tubes may be exhausted to varying degrees of attenuation, and produce differing effects according to the degree of exhaustion. When the hand is placed near such a tube a shower of free sparks will issue from the surface of the electrode. The current thus observed is produced by induction, there being no conduction current through the glass. We may, however, call it a displacement current, as already explained earlier in the chapter, since, according to the view of Clerk Maxwell, all circuits are, properly speaking, closed circuits.

It is usual, however, to apply a vacuum tube directly to the surface of the body. The spark gap being thus largely eliminated, there is but little sensation, though it is necessary, in order to avoid possible irritation of the cutaneous surface, to move it from place to place.

CHAPTER XVI

PHYSIOLOGICAL EFFECTS OF STATIC AND HIGH FREQUENCY DISCHARGES

Should we pursue the same line of investigation with static charges as was followed in Chapters IV and V with direct and induced currents, we should discover that the chemical effects peculiar to the direct current are largely wanting, and that electrolysis of fluids and diffusion of ions are practically negligible. This springs from the fact that static discharges, while of high voltage, are of small amperage, and that effects resulting from electrolysis and phoresis are dependent upon quantity, not pressure. It has been said that where diffusion of ions occurs from either pole of a static machine, it is due to electrical bombardment rather than a true phoresis. Yet Rohbrausch found that a sixteen plate Holtz machine, making five turns in three seconds, produced a constant current which was capable of decomposing water at the rate of three and one half millionths of a milligramme in a second.

Since currents of high frequency and high potential are produced by static machines as well as by induction coils, it is deemed best to consider the physiology of both static and high frequency currents at this point.

Sensory Effects.— If two persons be placed in the external circuit of a high frequency apparatus with an incandescent lamp of one hundred and twenty-five volts and one ampere interposed between them, it will light up without imparting any sensation to the persons in the circuit. D'Arsonval submitted himself to an experiment of this kind, in which a current of three amperes was passed through his body without sensation, except a slight feeling of warmth at the point of exit and entry. Figure 144 represents the manner in which the experiment may be performed. Therefore, *high frequency currents produce no sensory effects between the poles.*

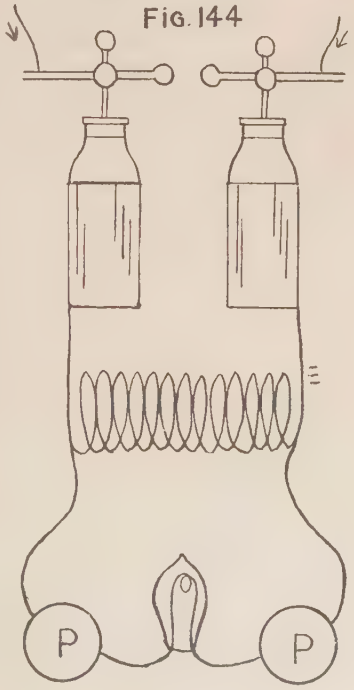


Fig. 144

We must carefully distinguish the effects here noted from the effects produced by a spark or an effleuve. The former will produce cauterizing effects and may be used successfully in this way for the destruction of normal and pathologic tissue, as well as for counter-irritation. The latter produces a sensation of warmth over the area treated.

Motor Effects. — If the metallic electrodes connected with the

external armatures of the Leyden jar of a static machine be grasped with the hands, upon separating the sliding rods a short distance, the muscles of the arms are found to contract violently and painfully. Therefore, *oscillatory currents may produce muscular contraction.*

This observation, however, is true only of relatively low frequencies, and is not applicable to frequencies that are properly characterized as high. When they attain a rapidity of ten thousand oscillations per second they produce neither sensory nor motor effects.

Inhibitory Effects.— D'Arsonval draws attention to what he calls the inhibitory action of high frequency currents. Thus (1) if a high frequency current is applied to the surface of the body for a short time, local anesthesia may occur at that point, lasting from one to twenty minutes. (2) In like manner after the application of a high frequency electrode to the body, the sensibility of the skin to direct and induced currents is much diminished. (3) Under the influence of these currents arterial tension in a dog falls a number of centimeters.

Bactericidal Effects.— Experiments published by D'Arsonval and Charrin tend to prove *that high frequency currents are bactericidal.*

The method adopted was to immerse a small coil of wire in a U-shaped tube containing broth and pus-producing bacteria. After a half hour the culture was discolored and the bacilli destroyed.

Other experiments published by M. Dimitri-

ewski have tended to prove that toxins submitted to the effleuve lose their toxicity and become harmless. Later experiments by the auto-conduction method upon tuberculous guinea pigs produced an inflammatory area around pulmonary foci, which finally abated, leaving them free from bacilli.

These conclusions as to the bactericidal effect of high frequency currents have been disputed by other investigators, some affirming that the effects obtained by D'Arsonval were due to heat. It is probable that the passage of high frequency currents through culture media may alter their nutritive properties, and thus injure the development of bacteria.

Again, it has been denied that toxins submitted to the action of high frequency currents lose their toxicity, while it is admitted that their virulence may be attenuated.

Where, however, a high frequency discharge is made directly upon colonies of bacteria, it is admitted that a destructive effect has been exercised.

Effects upon Urinary Elimination.— Upon the question of urinary elimination there is a general agreement among investigators, that the application of high frequency currents increases the amount of urine excreted, as well as the quantity of urea, uric acid, total nitrogen, phosphates, sulphates, and chlorides.

Effects upon Respiration. — The conclusions of D'Arsonval upon the effects of the general application of high frequency currents upon respira-

tion have been confirmed by other investigators. These are: (*a*) that there is an increase in the number and depth of respirations; and (*b*) that there is an increased activity in the processes of respiratory combustion, as evidenced by the amount of oxygen absorbed and carbon dioxide eliminated in a fixed unit of time.

Production of Heat.— Elaborate experiments by D'Arsonval and others prove that the general application of high frequency currents results in an increased production of heat. Quite apart from such experiments, it would follow as a result of the increased vigor of combustion, due to general electrization by high frequency currents, that there would be an increased heat production. This has been estimated to be from seventy-nine to one hundred and twenty-seven calories per hour, the temperature of the body continuing normal.

Increased Activity of the Sweat Glands.— It is a matter of clinical observation that the general application of high frequency currents will frequently produce marked diaphoresis.

Radioactive Effects.— It is probable that there is a radioactive effect proceeding from vacuum tubes energized by high frequency currents. As, however, these tubes are not focused, it is probable that the radioactive effect has little penetration.

Vaso-Motor Effects.— Where a rabbit is subjected to high frequency currents, it is noted that the vessels of the ear rapidly dilate, as when the sympathetic nerve is cut. They soon, however, contract.

The observations of D'Arsonval referred to above, that arterial pressure was reduced in a dog under the influence of high frequency currents, has been, according to careful clinicians, repeated in patients suffering from arterio-sclerosis.

Effect upon Circulation.— After much experimentation and apparent diversity of conclusion, there is now a general agreement that D'Arsonvalization, particularly by the auto-condensation or auto-conduction method, *produces a fall in blood pressure.*

CHAPTER XVII

PHYSICS OF THE ROENTGEN RAY

In 1895 Wilhelm Conrad Roentgen discovered a peculiar emanation from a Crookes tube with which he was experimenting, which for want of a better name he called the X-ray. The Crookes tube, named after its inventor, Sir William Crookes, the great English

Fig. 145.

chemist, is a tube which has been exhausted to about a millionth of an atmosphere. It differs from a Geissler tube essentially in the degree of exhaustion, the latter having a much lower vacuum.

The Geissler tube (*Fig.* 145) lights up with successive colors when electrically excited, as it passes

from a lower to a higher vacuum. When it attains a very high vacuum it ceases to glow, but instead shows a peculiar fluorescence of its walls, which is of a pale yellowish-green color if the tube is made of soda glass, and of a bluish color if it is made of lead glass. This fluorescence is due to the impingement of a stream of negatively charged particles upon the walls of the tube, which Lenard called "kathode rays." He had noted that these so-called kathode rays produced some slight effects outside of the tube. It was reserved for Roentgen to show that there was another ray of a different character outside the tube, which had the power of penetrating opaque bodies, and producing impressions upon photographic plates. Moreover, the X-ray was shown to be a true ray, that is to say, a radiation or disturbance in the ether, while the kathode ray is a stream of negatively charged electrons flowing from the kathode. The latter are acted upon by a magnet and can be deflected from their course; the former are not subject to magnetic influence.

The X-rays are produced by the impact of the kathode stream upon a solid body which arrests the course of the moving particles. The disturbance thus set up in the ether gives rise to the marvelous phenomena of the X-ray. The radiations thus set up differ from light in that they consist of irregular, solitary impulses, while light radiations are made up of undulations following one another in regular sequence.

The following are some of the interesting prop-

erties of the X-ray: (*a*) It penetrates opaque bodies in a ratio inversely proportional to the atomic weights of the substances upon which it falls. Thus sulphur with an atomic weight of thirty-two is less transparent than aluminium with an atomic weight of twenty-seven. Lead with an atomic weight of two hundred and six and platinum with an atomic weight of one hundred and ninety-seven are highly resistant to the passage of the X-ray. (*b*) It has the power of acting upon the sensitive salts of silver, as light does. (*c*) It travels at about the velocity of light. (*d*) It is not refracted when passed through prisms of aluminium or ebonite. (*e*) It is not concentrated by a lens. (*f*) It is not regularly reflected. (*g*) It is capable of polarization. (*h*) It excites fluorescence in certain substances, especially the platino-cyanides of barium and potassium, some uranium compounds, zinc sulphide and calcium tungstate. (*i*) It discharges an electrified body by ionizing the surrounding air. (*j*) It also imparts a positive charge to bodies upon which it falls, by weakening the atomic cohesion, so that negative electrons are detached and the latter projected.

Production of X-rays. For the production of X-rays there are needed a Crookes tube with suitable modifications and an electrical apparatus for the supply of currents of suitable potential and quantity. Currents of sufficient electromotive force are obtained from induction coils, static machines, and high potential transformers. Undoubtedly the induction coil is most extensively used for the production of the

X-ray, where rapidity of action is desired and large currents with high electromotive force are required. It is not denied, however, that the static machine when supplying currents of sufficient amperage is admirably adapted to X-ray work, since the current

Fig. 146

which it supplies is unidirectional, and for this reason will give better results than a coil furnishing an equal amperage. The current furnished by a coil is interrupted, and while the inverse current is largely suppressed by a suitable adjustment of inductance, capacity, and resistance, there is a large aggregate of time during which the current, owing to interruption, does not flow. For a given result, therefore, higher amperages are necessary in a coil than in a static machine, where the currents are continuous and with-

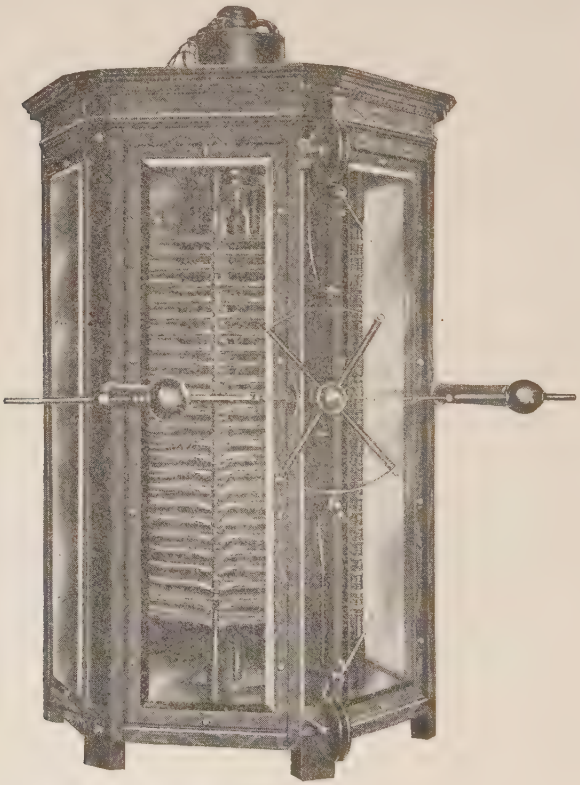


Fig. 147.

out interruption. It would thus appear that all that is needed to make the static machine an ideal machine for the production of X-rays is the increase of amperage. With the introduction of high speed machines this desideratum has been attained. Since the amperage of a static machine is directly proportional to the speed of rotation of the plates, it is evident that it is possible to construct a static machine that will furnish a sufficient output to meet all the demands of expert X-ray work. Figure 146 represents a twenty plate static machine manufactured by the R. V. Wagner Company, Chicago. Figure 147 represents a static machine having fifty revolving plates manufactured by the same company. The shaft is vertical and the plates are enclosed in a hexagonal cabinet. It would seem that the enormous output of a machine of this description would make it equal to every demand of modern diagnostic and therapeutic work.

The skiagraphs produced by the static machine are characterized by richness of detail and accuracy of focus. Moreover, the continuous character of the currents produced by static machines renders them less destructive to the tubes employed.

High potential transformers may also be used in X-ray work. For therapeutic uses they give satisfactory results; for expert fluoroscopic and skiagraphic work they leave much to be desired, and readily concede the superiority to induction coils and static machines of sufficient amperage.

Figure 148 represents an induction coil manu-

factured by the E. B. Meyrowitz Co., of New York.

More recently a new type of generator for exciting X-ray tubes has been introduced under the name of the Snook Roentgen Apparatus. Here the direct current from the commercial mains runs a rotary converter (*Fig.* 49, *Chap. II*), which supplies an alternating current to a closed magnetic circuit, step-up transformer. (*Fig.* 45, *Chap. VI.*) This current is changed into a unidirectional current by means of a rectifying switch, mechanically attached to the shaft of the rotary converter. The apparatus for use upon the alternating current mains requires an additional motor. The advantages claimed for the Snooks Roentgen apparatus are exemption from troubles due to interrupters, inverse currents, breakdowns, and powerful external magnetic fields. (*Fig.* 149.)

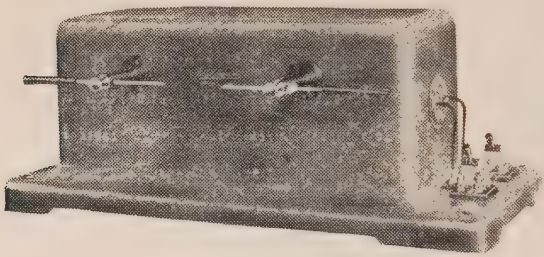


Fig. 148.

X-ray Tubes. The X-ray tube (*Fig.* 150) is a modification of the Crookes tube. It consists essentially of a bulb of glass exhausted to about a millionth of an atmosphere, with a constricted portion at either end through which the terminals are admitted. The terminal connected with the kathode is expanded at its inner end into a concave disk of aluminium, from which the kathode stream may easily pass and center

upon the anode which is admitted through the constriction at the opposite end. This is expanded at its inner end into a flat surface of platinum upon which the kathode stream strikes, generating the peculiar etheric disturbance called the X-ray. Aluminium is selected as the material composing the kathode, because it does not throw off metallic particles

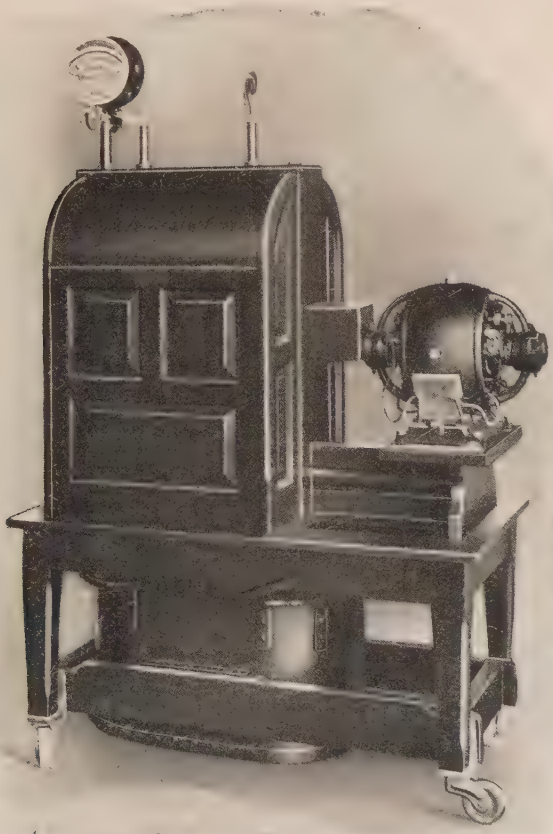


Fig. 149.

which collect upon the sides of the tube and tend to diminish its transparency. Platinum is usually employed for the target of the anode, though nickel is also used. It is usual to introduce a stem supporting a target between the anode and kathode, placing it a

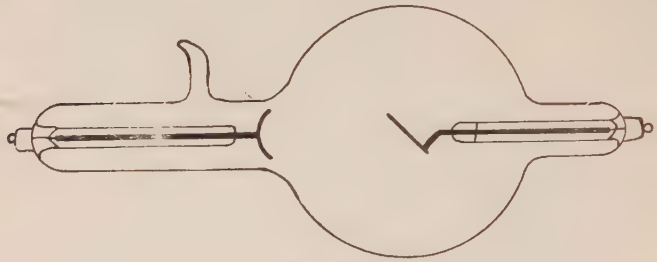


Fig. 150.

little back of the focus of the kathode. This is then called the anti-kathode.

Tubes which have been used for some time offer greater resistance to the passage of the current between anode and kathode. Such tubes are called

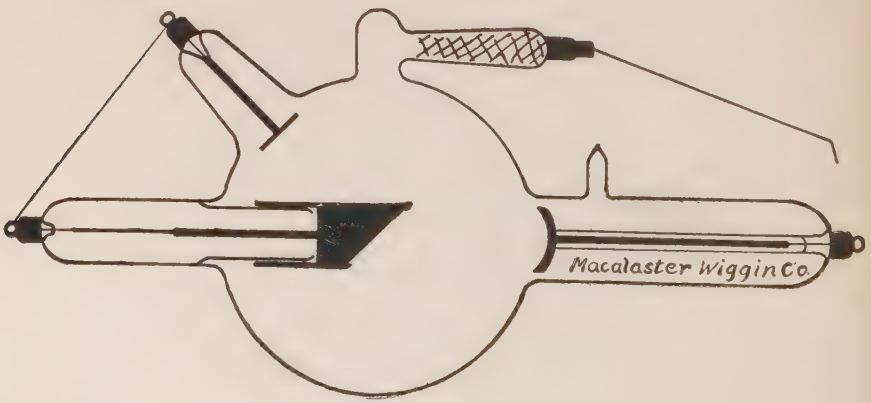


Fig. 151.

" high," and are sometimes too resistant to the current to become excited. Formerly such tubes were put into an oven and baked, the heating process forcing into the tube some of the gases which were occluded in its walls, and so reducing its vacuum. It is now customary to construct tubes with one or more valves for the purpose of regulating the vacuum. Thus in Figure 151 a valve is provided containing a salt, as chlorate of potassium. An arm is seen passing from the valve to the kathode. By approximating this arm to the kathode a portion of the current is passed through the salt, liberating sufficient oxygen to reduce the vacuum and make the tube serviceable for the purpose in hand. The same effect may be produced by introducing a platinum wire into the tube by a side branch. Platinum has the power of occluding hydrogen when heated. If now the wire is heated by a spirit lamp, hydrogen will enter the tube and lower the vacuum.

In order to resist the heating action of large currents upon the target, it is often reinforced by a thick layer of metal or cooled by a column of water. Figure 152 represents a tube provided with a water-cooling device.

Estimation of the Vacuum. It is customary to estimate the degree of exhaustion of the tube by the equivalent distance between the sparking terminals which it will " back up." As a tube is placed in shunt with the sparking terminals the current will pass through the parts of less resistance, and where the tube offers the greater resistance, the current will

leap across the sparking terminals. Thus a tube is said to back a sparking distance of two, four, or more inches.

Piffard Safety Tube. This tube, illustrated in Figure 152A, is made entirely of lead glass with the

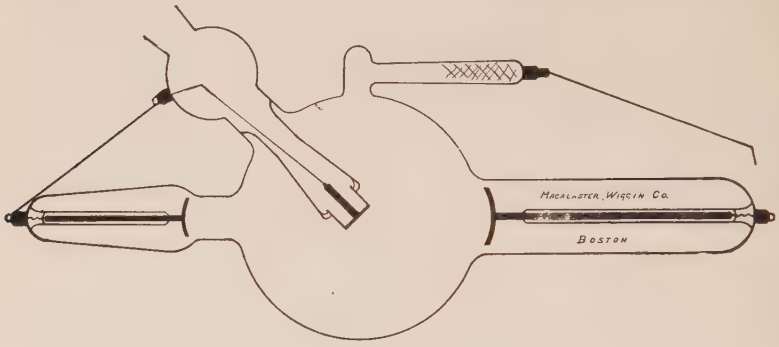


Fig. 152.

exception of a flint glass window. As lead is opaque to the X-ray, the effective ray can pass out only through the flint glass window.

Cornell Tube. This tube, of which an illustration is given in Figure 153, is designed to be applied directly to the area to be treated. It is asserted that no cases of X-ray dermatitis have ever occurred with the use of this tube. The inquiry may fairly be raised whether this exemption from untoward effects may not be due to the very small volume of X-rays excited in this tube.

The Fluoroscope. The fluoroscope depends for its efficiency upon the fact that certain minerals, like platino-barium cyanide, willemite, or tungstate of calcium, fluoresce under the influence of the X-ray.

The X-ray is, like light, invisible, but has the property of rendering luminous certain minerals upon which

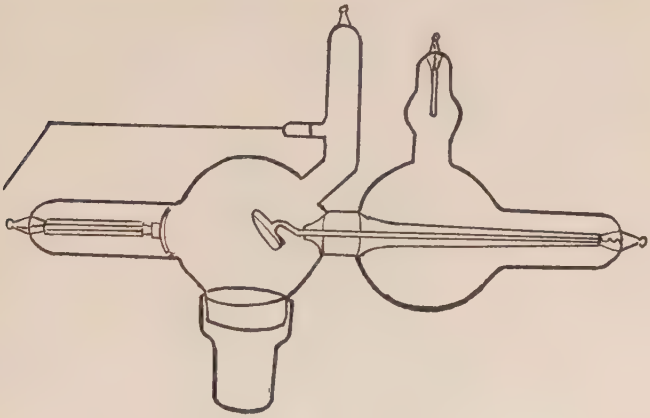
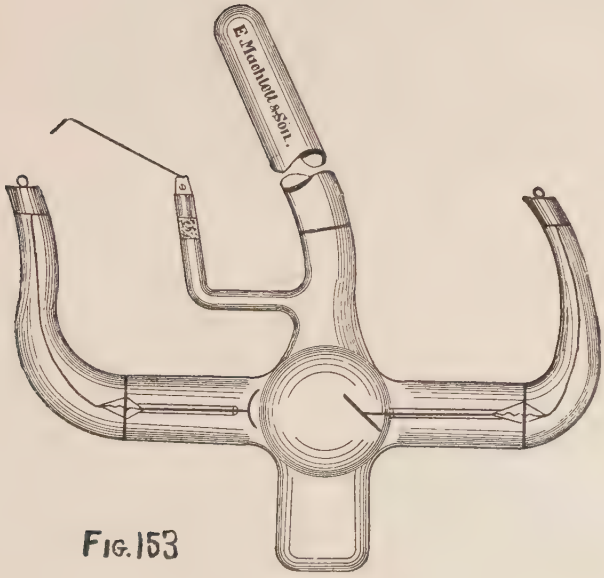


Fig. 152A.



it falls. Certain other minerals have the power of remaining luminous a longer or shorter time after irradiation by the X-ray. These are said to be in a state of phosphorescence. They are not, however, so suitable for X-ray purposes as the minerals just mentioned. It is customary to spread crystals of

Fig. 154.

platino-barium cyanide upon a square of ground glass, attaching them to the surface, preferably, with wax, instead of varnish, inasmuch as with the latter the salts are apt to deteriorate with age. The screen is so constructed that it may constitute the anterior portion of a box shaped like a stereoscope, and so made that it fits closely about the eyes and nose and

thus excludes the light. The interior of the box is painted black in order to absorb all light rays.

Figure 154 illustrates a fluoroscope made by the R. V. Wagner Company, of Chicago. If the screen shows a bright yellowish green, it is likely to be in good condition; if it shows an orange or brown color, it has lost its highest fluorescent power. Screens are also made without the box attachment above described, in which case they cannot be used unless the room in which the examination is made is thoroughly darkened. Under any circumstances it is desirable that light be largely excluded in order that the eyes may become accustomed to the darkness and thus be more sensitive to the fluorescence of the screen.

CHAPTER XVIII

PHYSIOLOGY OF THE ROENTGEN RAY SKIAGRAPHY. APPARATUS

PHYSIOLOGY.— (1) There appears to be little or no sensation produced by the action of the X-ray. Patients sometimes declare that they experience a sensation suggesting a slight contraction of the skin.

(2) When, however, exposures have been allowed to continue for some time, the skin becomes tanned and later atrophied, the hair falls out, and the sweat glands cease to produce their characteristic secretion.

(3) If the exposures continue without interruption, a dermatitis may ensue, followed by necrosis both of the skin and underlying tissues. Pain now becomes a prominent and persistent symptom.

(4) Where a neoplasm stands above the surface of the skin, it undergoes contraction.

(5) Pain is frequently relieved when due to inflammatory or malignant conditions.

(6) Congestion is diminished.

(7) Ulcerating surfaces acquire a glazed appearance under irradiation. Each of the physiological conditions above described may be explained by contraction of the tissues submitted to X-ray

irradiation, in consequence of which the blood supply is diminished, relieving abnormal conditions characterized by congestion, and producing atrophy and necrosis where irradiation is too long continued.

(8) While it has not been shown that bacteria are destroyed by the X-ray, it is probable that the nutrient media subjected to irradiation are less favorable to bacterial growth.

Idiosyncrasy. It has been affirmed that there is an idiosyncrasy to X-ray irradiation, and that the operator should proceed cautiously before subjecting his patients to regular and successive exposures. That such idiosyncrasy does exist cannot be doubted, and it is a safe rule to begin treatment with short exposures and longer distances, until the question of idiosyncrasy has been decided.

It has been stated that blondes are more likely than brunettes to develop a dermatitis from X-ray exposures. If this is true, it may be assumed that the relative absence of pigmentary deposit may render the tissues more liable to damage.

Cumulative Action. After a time the tissues manifest, in some instances, an intolerance to further exposure and tend to break down. This would seem to indicate a persistence of the tissue contraction to which reference is made above.

X-ray Dermatitis. The dermatitis that sometimes results from the administration of the X-ray may be divided into three degrees. (*a*) Dermatitis of the first degree is characterized by hyperemia, infiltration, exfoliation, intense itching, and increased

temperature. (*b*) Dermatitis of the second degree is characterized by the formation of blisters, and other symptoms of inflammation, pain being very marked. (*c*) Dermatitis of the third degree is characterized by necrosis of tissue with areas suggestive of dry gangrene.

Skiagraphy. This term is derived from the Greek *skia*, shadow, and *graphein*, to write. The term is well chosen, since an X-ray picture is a shadow picture, or an expression in shadows of the relative penetrability of the tissues traversed by the X-ray. The relative penetrability of physiological and pathological structures is in the following order, beginning with the tissues having the least penetrability: bone, muscle, blood, cartilage, pus, fat, and skin.

When skiagraphs are examined, it must be remembered that the denser tissues appear upon the plate or film as lighter shadows, since they represent the tissues which have acted as obstructions to the free passage of the ray, the other tissues appearing dark. This condition is, however, reversed in the prints which are taken from film or plate, the denser structures now appearing dark and the less opaque structures light.

Sensitized Plates. The same plates may be employed for radiography as for photography. Where, however, it is desired to secure greater detail, extra sensitive plates having a double coating may be employed. Plates or films should be kept at a considerable distance from an excited tube in order to avoid fogging. Otherwise they should be placed in a lead-lined box.

Choice of Tube. Where it is desired to determine the presence of a foreign body, opaque to the X-ray, a high vacuum tube is to be preferred. Where the body sought for is easily penetrated, as, for instance, a calculus, a low tube should be selected.

Distortion. It is constantly necessary to guard against the danger of distortion. This is to some extent unavoidable, since the rays proceed from a common point like the radii of a circle, and the outer rays, falling obliquely upon the object to be skiagraphed, will project an elongated shadow, the perpendicular rays, only, giving a shadow free from distortion. Figures 155, 156 give a graphic representation of the difference in the shadow cast by rays proceeding from a point, and those which are projected from a radiating surface of equal area with that which is to be skiagraphed.

These figures likewise show the desirability of so

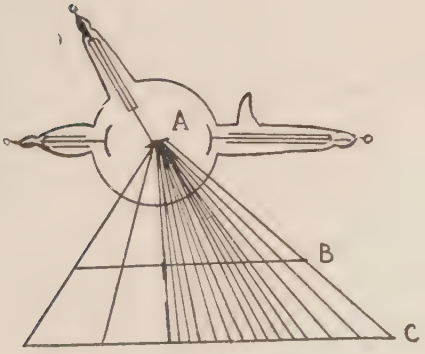


Fig. 155.

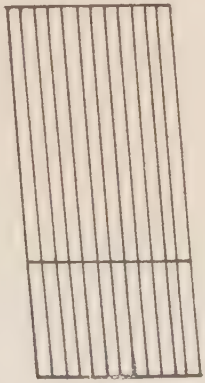


Fig. 156.

placing the tube that the plane of the target is parallel with that of the area to be skiagraphed, the most active rays being perpendicular to the object which the operator seeks to discover. In this respect, however, the practice of operators is not uniform, many preferring to place the tube in such a position that a line running from anode to kathode is parallel with the object to be skiagraphed.

The above figures will also show that a skiagraph upon a sensitized plate or film represents the parts in their normal relation, which is reversed in the print. On the other hand, an object photographed by a lens

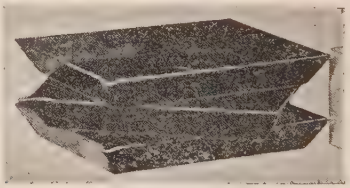


Fig. 157.

is reversed, the print restoring the parts to their normal relations.

The Development of Skiagraphs. This does not differ essentially from the development of photographs. The exposed plates or films are removed from their coverings in a dark room which is illuminated by the faint glow of a ruby lamp covered with orange paper or glass. Three trays (*Fig.* 157) are provided and placed side by side. The first contains the developing solution, which is especially recommended for the variety of plate or film employed. The second contains water in which the plate or film

is to be washed after removal from the developing solution. The third contains a solution of acid hypophosphite of soda which is used for fixing. After removal from the fixing bath the plate or film is placed in a pan or other receptacle, where the water is constantly renewed, and allowed to remain for an hour or more. The process of developing requires much skill, in order to enable the operator to secure the results which he seeks. Therefore, it is better for him to develop his own plates and films rather than to entrust them to a photographer, who may not be aware of the results which are especially sought. It is not the purpose of this chapter to furnish the complete technique of skiagraphic development, as this is readily found elsewhere, but rather to call attention to some useful points that are sometimes overlooked. After the immersion of the plate or film in the developing fluid, the outline of the image will soon appear, and if the solution is too strong or the exposure has been too brief it will soon disappear. In this case the solution should be diluted with water, or be modified by the addition of a few drops of a ten per cent solution of bromide of potassium, called a retarder, or the plate or film immediately removed. Where definition and not detail is sought, as with a high vacuum tube, the development may be carried to the point where the image grows dark and begins to disappear from the plate. Where detail is sought, the process of development should be slower, the solution may be diluted with water or modified by addition of the retarder, or the plate or film quickly removed.

Experience and good judgment must determine when the development has been carried to the right point.

Examination of Skiagraphs. For this purpose the skiagraph may be held between the observer and a good light; or it may be examined in a dark room by means of a box provided with a ground glass window and an electric lamp in the interior. (*Fig.* 158.) The skiagraph is laid upon the ground glass window, where its lights and shadows are displayed to excellent advantage.

Titubator. When a plate or film is ready to be placed in the developing fluid, it should be quickly

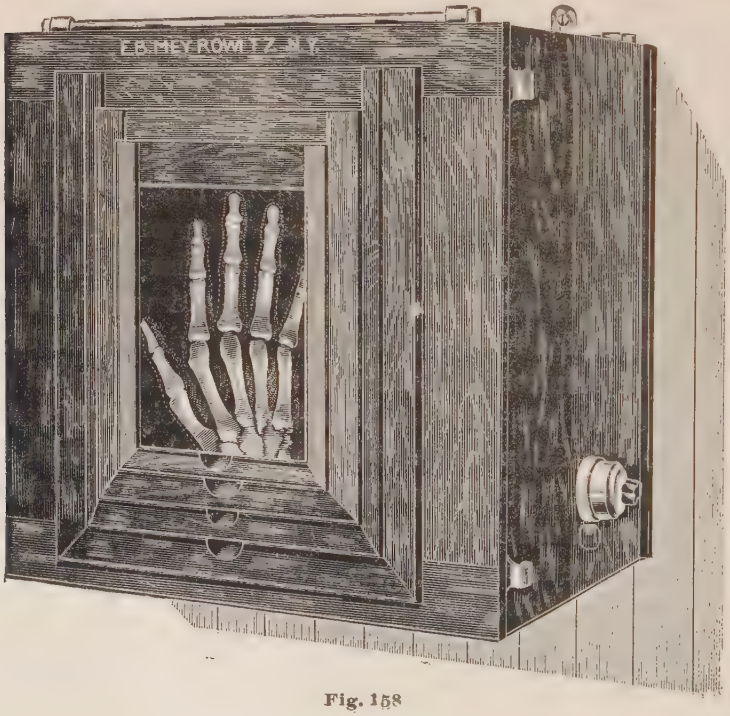


Fig. 158

immersed in order to secure a practically instantaneous wetting of the sensitized surface, and any air bubbles which form upon the plate should be carefully brushed away by a tuft of cotton or other substance. The plate or film should then be kept in more or less constant motion by a rocking of the tray. This may also be accomplished, if thought desirable, by a device called a titubator, in which the rocking motion is mechanically effected. (*Fig.* 159.)

Printing. This process does not differ essentially from the same process in photography. There

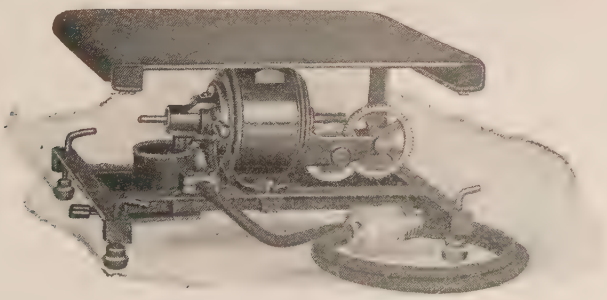


Fig. 159.

are numerous papers on the market, some requiring sunlight and others lamp or electric light for printing. By employing the same plates, films, paper, and developers, the operator is more likely to acquire certainty and confidence in his technique, than if he passed frequently from one set of conditions to another. Developing and fixing prints demand less judgment and experience than the corresponding treatment of plates and films.

Stereoscopic Skiagraphy. This is effected by taking two skiagraphs at slightly different angles so

as to reproduce the conditions of binocular vision. The skiagraphs, when thus viewed in an X-ray stereoscope, have their retinal impressions superimposed, and stereoscopic, that is to say, the different planes constituting the object under examination are no longer merged into one plane, but are separated, and the different details stand out in their proper relation in space.

Instantaneous Skiagraphy. To accomplish this result, powerful coils are generally demanded, and the tube is placed near the object to be skiagraphed. The indication for its use is the discovery of calculi, or the examination of chest or abdomen, where the excursions of the diaphragm interfere with the accuracy of the skiagraph. The same result may be obtained by accurately timing successive exposures, so that the irradiations occur with the diaphragm always in the same position.

Localization of Foreign Bodies. When foreign bodies are near the surface there is little difficulty in localizing them. When, however, they are in the deeper tissues the problem of finding them becomes at times very difficult. Where the foreign body is of metal and deeply situated a high vacuum tube should be employed. Where the material is easily traversed by the rays, a tube of low vacuum should be selected, since detail is of the first importance.

Davidson's Localizer. An instrument called Davidson's localizer may be employed for the purpose of localizing foreign bodies. It can readily be seen that, if a skiagraph be taken of a given area at a given

distance from the tube, and a second skiagraph be taken with the tube at a measured distance from the first position, then the displacement of the foreign body in the two skiagraphs will enable the operator, by a simple calculation, to locate its distance from the plate. The process is simplified by carrying two threads from the positions of the tube to the two positions of the foreign body in the skiagraphs. The point of intersection will be the position of the foreign

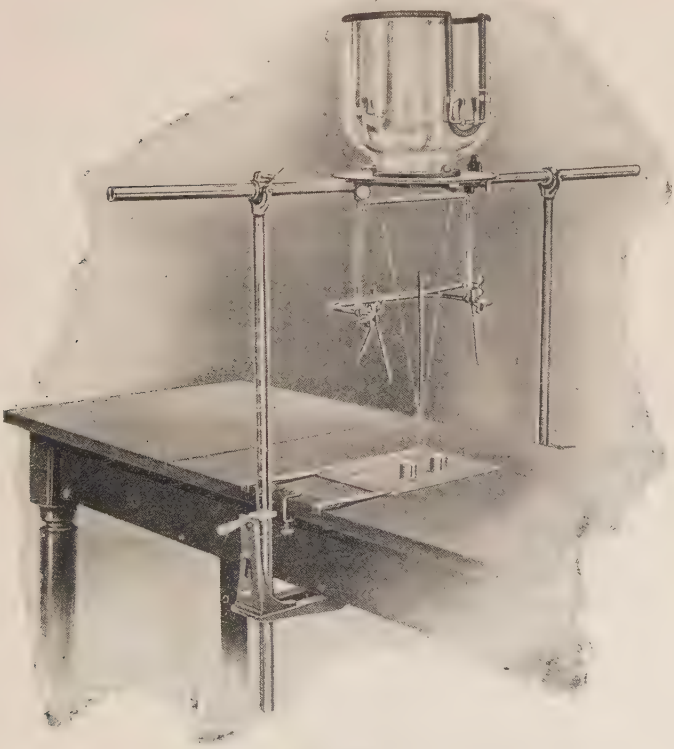


Fig. 160.

body in the tissues in the horizontal plane. Its location in the vertical plane is denoted by the image of a cross wire dipped in an aniline dye, which is used to tie the envelope containing the plate to the body of the patient. The mark of the wire is also left upon the skin, so that the surgeon can readily ascertain the location of the foreign body. Steroscopic skiagraphy accomplishes the same results, furnishing a startling localization in space of the object sought.

Figure 160 represents a combination of localizer, tube, shield of lead glass for reception of X-ray tube and compression diaphragm, made by the Roentgen Manufacturing Company, of Philadelphia.

Bismuth Compounds in Radiography. For purposes of diagnosis bismuth compounds — bismuth subnitrate, bismuth subcarbonate, bismuth oxychloride — may be employed in the examination and study of tubercular and other sinuses. An aqueous mixture, or a mixture of bismuth and vaseline is injected into a sinus, as, for instance, a rectal fistula. Since bismuth preparations are opaque to the X-ray the direction and extent of fistulous passages are readily displayed upon the skiagraphic plate. An interesting sequel of the diagnostic use of the bismuth preparations has been the discovery, that the distention of sinuses by the method just described becomes a curative procedure.

Current in an X-ray Tube. The current through an X-ray tube may range from a fraction of one milliampere to thirty or more milliamperes. In a high speed static machine of ten pairs of revolving plates of

the Wagner type, the tube circuit will show as high as eight or ten milliamperes, and with an increase in the number of revolving plates the amperage is still further increased. For therapeutic purposes small currents varying from a fraction of a milliampere to perhaps one milliampere are sufficient. For diagnostic purposes, and especially instantaneous radiography, much larger currents are demanded.

Product of Amperage and Time. Upon what factors does the energy of the X-ray depend? D'Arsonval has shown that the results upon the sensitized plates are identical when the product of amperage into time are equal. Thus an exposure of forty-five seconds with .45 milliampere was exactly equal to an exposure of twenty seconds with 1.00 milliampere, and to another of fifteen and five tenths seconds with 1.25 milliamperes, since the three products are approximately equal.

Voltage. Another question has been raised: Is X-ray production proportional to voltage or to current? Professor Wertheim Salomonson has maintained the former view, while D'Arsonval has shown a series of skiagraphs in which the effect was proportional to current and was independent of the number of volts expended.

Comparison of Radiation. Quality. To determine the penetration of X-ray radiation, a rough approximation may be made by noting the sparking distance between terminals arranged in shunt with the X-ray tube, as already explained. This method is, however, very unsatisfactory, since quantity of radi-

ation and quality of radiation are quite distinct. Another method is to compare the relative opacities of various bodies, as when the hand is placed in front of the fluoroscope. When the bones appear dark the tube is said to have a low degree of penetration, when they appear light and only slightly darker than the surrounding tissues, the tube is said to have a high degree of penetration. A third method, which, however, depends in principle upon the method just described, is illustrated by Benoist's radiochromometer. This consists of a disc of aluminium, whose center is replaced by a circular piece of sheet silver 0.11 millimeter in thickness. The surrounding portion of the disc is divided into twelve sectors, of progressively increasing thickness. When used to estimate the penetrating power of a tube, the radiochromometer is placed in front of a fluoroscope and the shadows of the sectors compared with the shadow of the silver plate. With a tube of high penetration the tenth sector will cast a shadow equal to that of the silver. Figure 161 represents an improved radiochromometer incorporating Benoist's latest suggestions. Here the

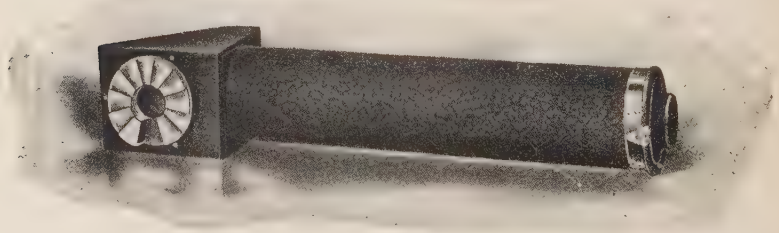


Fig. 161.

sectors are in the same plane as the tube, and the image on a fluorescent screen immediately behind is reflected by a mirror into the eye of the observer.

Quantity. The methods referred to above are designed to estimate the quality of the X-ray issuing from a tube. To estimate the quantity is a still more difficult problem, for which several solutions have been proposed. Among others Sabouraud and Noiré have employed pastilles of platino-barium cyanide. These undergo a gradual change from a yellow to a brown color under the influence of the X-ray. Thus if a Sabouraud pastille is placed midway between the antikathode and the irradiated area, a decided brown color is produced at about the time that the skin has received the maximum exposure without suffering a dermatitis. To this the symbol 5.H has been given. Thus 1.H is one fifth of the amount of radiation which the skin can stand without developing a dermatitis. 5.H represents the proper dosage for tinea capitis, and causes a loss of hair over the exposed part. A fresh growth will appear if this dose has not been exceeded. Figure 162 represents a book containing twenty-four Sabouraud's pastilles.

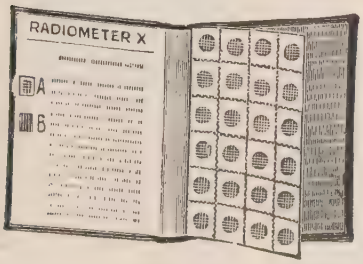


Fig. 162.

Protecting Devices. Tubes may be partially enclosed by means of shields made of rubber impregnated with lead or other opaque material. These are a useful protection both to the patient

and the operator. (*Fig.* 163.) The openings may be governed by the use of caps or diaphragms to which specula may be attached for further limitation of the area of irradiation. The hands may be protected by gloves of of a similar composition. (*Fig.* 164.) The operator may stand behind a screen made of light wood, lined with lead foil, and having a window of lead glass at the top. (*Fig.* 165.) In fact it is now possible to purchase protecting devices of every description to guard against the misfortunes which have overtaken the earlier students of X-ray phenomena. (*Fig.* 166.)

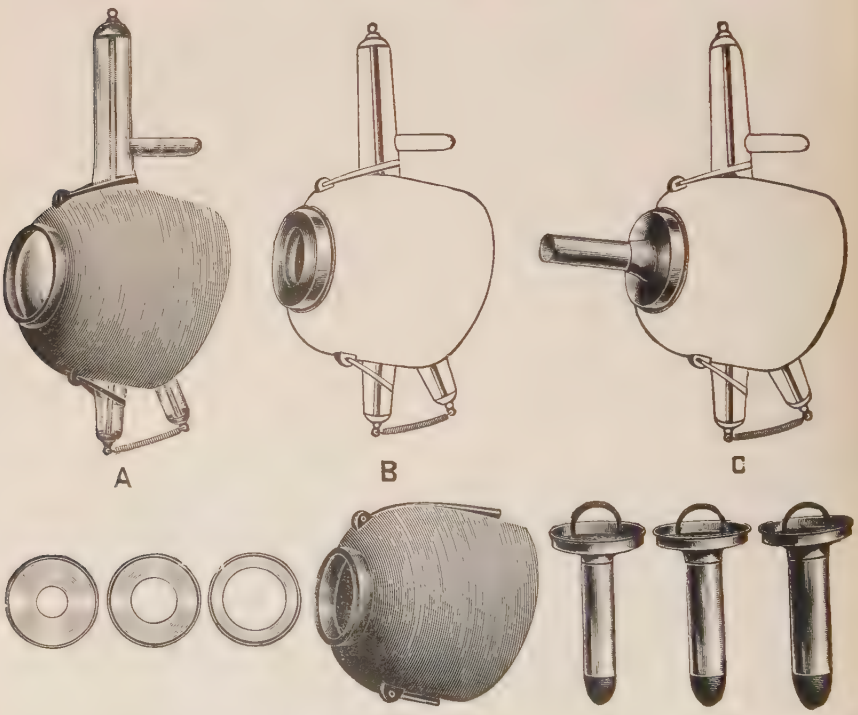


Fig. 163.

The dangers incident to frequent and repeated exposures must never be forgotten, and too much care cannot be exercised in protecting oneself against possible damage, not only to the superficial structures, but to the deeper glandular tissues to which the X-ray easily penetrates.

Fig. 164.

Fig. 165.

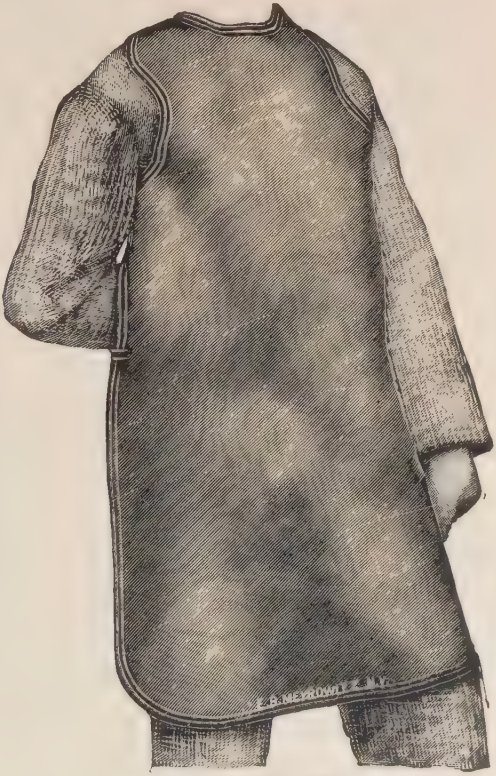


Fig. 166.

CHAPTER XIX

DENTAL SKIAGRAPHY

The application of the X-ray to the determination of oral conditions has yielded results of a highly satisfactory nature. As early as February, 1896, two months after the discovery of the X-ray, Professor Koenig showed a skiagraph of the teeth to the Society of Physics at Frankfort, Germany, and in June, 1896, seven months later, *Dental Cosmos* published an article by Dr. W. J. Morton, of New York, entitled, " X-rays in Dentistry."

For the examination of the teeth and associated structures two methods may be employed. These are (1) fluoroscopic and (2) radioscopic. The fluoroscopic method employes an instrument called the dental fluoroscope. This is a flat disk of ground glass covered with platino-barium cyanide and attached to a metal stem. This is introduced into the mouth of the patient in such a position as to receive the shadow of the area under examination upon the ground-glass screen. Platino-barium cyanide, as already explained, has the property of fluorescing under the influence of the X-ray, and thus revealing by variations in density the character of the tissues through which it passes. In this examination the

patient and operator together with the focus tube are preferably in a darkened room, or a dark cloth may be used to exclude the light, being thrown over both patient and operator. The fluoroscope is of slight value in dental skiagraphy.

The radiographic method is of very great utility. This includes the use (*a*) of films placed within the mouth behind the area to be examined, and (*b*) of plates placed external to the teeth. The former consist of celluloid coated with a sensitive emulsion similar to that employed in the ordinary folding kodak. They are supplied by the manufacturer, in black envelopes, two films being in each envelope with the sensitive surfaces turned in. The dimensions of the envelope are $1\frac{1}{4}$ by $1\frac{5}{8}$ inches.

It is well to undertake to obtain a skiagraph of not more than one or two teeth at a time, since the curve of the jaw will necessarily produce considerable distortion in outlying portions of the skiagraph. The target should, therefore, be adjusted so as to throw the rays as nearly as possible perpendicularly upon the parts to be skiagraphed. This will necessitate placing the tube at a considerable distance above the jaw when skiagraphs of the upper teeth are to be taken, in order to place the surface of the target as nearly as possible parallel with the surface which is to be skiagraphed.

The tube having been put in proper relation to the patient, the film is placed in his mouth and held in position by the fingers of the operator or his assistant. In order to avoid destruction of the film

by the saliva it may be wrapped in wax paper. The length of exposure will depend upon the character of generator used and the quality of the tube. For dental skiagraphy small portable coils may be used, requiring an exposure of from thirty seconds to a minute or more. Of these the Kni-low (*Fig.* 167) and the Victor (*Fig.* 168) do excellent work. Larger

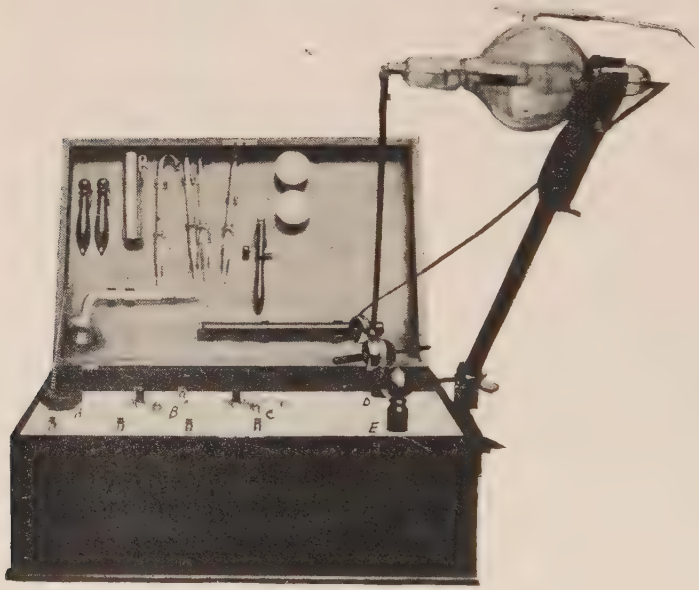


Fig. 167.

coils may of course be used, reducing the period of exposure if desired.

The static machine produces admirable results, the current being steady and small machines sufficient for satisfactory work. A high speed static machine (*Fig.* 169) having two revolving plates and producing

a current of from one half to one milliampere is admirably adapted for dental skiagraphy. This generator is almost noiseless and practically independent of weather conditions. The use of additional plates proportionately increases the amperage. There can be little question that a high speed static machine

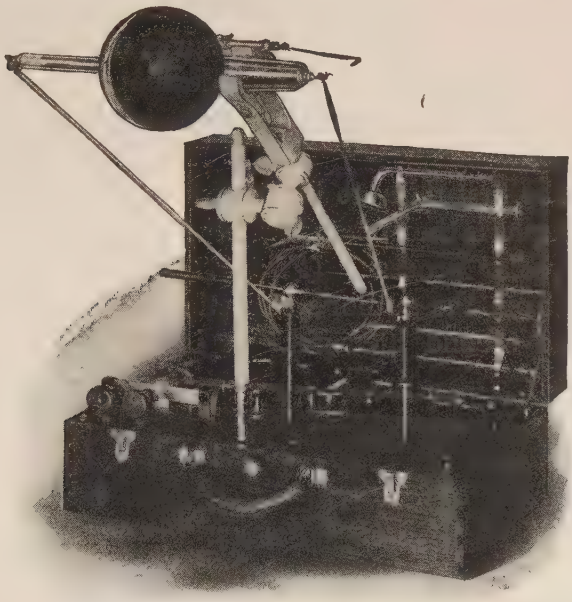


Fig. 168.

having a suitable number of plates is adequate to every skiagraphic demand.

Where it is desired to avoid exposure of the hand, the film may be attached to an impression of the jaw made with modeling compound. When the jaw is closed the film is held firmly in position. Figure 170 represents an impression of the teeth and jaw in

modeling compound. It is backed by a piece of aluminium plate.

Elaborate arrangements are not needed for successful work in dental skiagraphy. The patient may be seated in an ordinary chair, and as the period of exposure is not extended, it is not necessary to fix the head, though there is of course no objection to this procedure. The dental chair is well adapted for skiagraphic purposes. The development of films does not differ essentially from the technique already explained.

The first thing to be considered in the study of skiagraphs is the appearance of the normal tooth with its alveolar process. (*Fig.* 171.) This skiagraph, taken from the author's collection, represents an unerupted second bicuspid. It is introduced at this

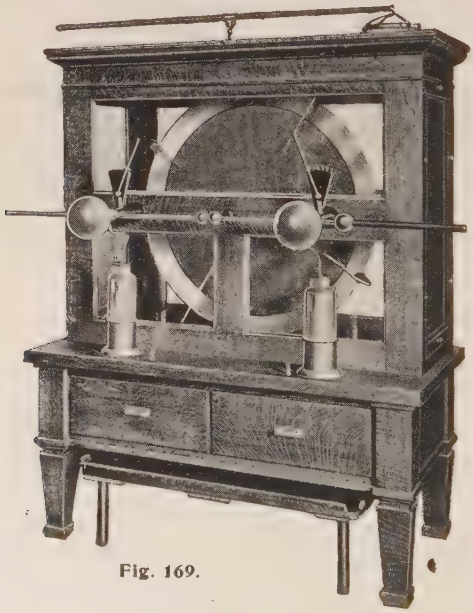


Fig. 169.

point, however, because it admirably displays in the film the characteristic condition of normal teeth and alveolar tissues. Here it will be seen that the teeth are indicated by a dark shadow through which runs a lighter shadow, which marks the root canal. Surrounding the tooth is a stippled or mottled shadow of less density than that which represents the tooth. This is the alveolar process, which is closely adherent to the tooth.

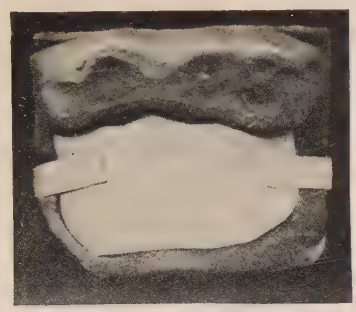


Fig. 170.

What modifications of this picture will occur in pathological conditions? These show themselves chiefly in the appearance of the alveolar tissues. These become lighter in color where there is pericementitis or pyorrhea, or where abscesses have formed and destroyed the structure of the alveolar tissue. In many cases the alveolar process is no longer closely adherent to the tooth, but is separated from it by an area indicated by a lighter shadow. Fillings and metal caps show dark. (*Fig.* 172.) This skiagraph recently made by the author shows a beautiful picture of the changes

Fig. 171

resulting from diseased structures. At the root of the left lateral incisor is seen a light area marking the site of a root abscess which has resulted in necrosis of tissue. The gutta percha root filling which passes almost to the apical foramen is clearly displayed. The frilling around the edges of the teeth indicates a pyorrheal condition approaching almost to pyorrhea alveolaris. These teeth had all become loosened as the result of disease in the alveolar process.

Fig. 172.

Fig. 173.

The skiagraph thus far described may be termed intra-oral. This method may be supplemented by the extra-oral method. This consists in skiagraphing the teeth with the accessory sinuses of the face upon a plate placed external to the mouth. (*Fig.* 173.) Here there is, of course, a certain superposition of images with a degree of confusion, resulting from the multiplicity of shadows. On the other hand, certain kinds

of information are obtained which are not to be secured by the intra-oral method. Among these are the relation of the roots of the molars to the floor of the maxillary sinuses. See Figure 174, in which the root of a molar is seen penetrating the floor of the maxillary sinus.

Occasionally such a radiograph will reveal the presence of a broach in the maxillary sinus which has given rise to the production of pus, and thus dis-

Fig. 174.

Fig. 175.

close the necessity of drainage through the socket. Figure 175 represents a skiagraph in which a broach has been introduced through the root of a molar into the maxillary sinus and orbit. It will also reveal peculiarities in the formation of the floor of the maxillary sinuses, indicating the point of election for drainage in cases of empyema of the maxillary antrum. Since the ethmoid and frontal sinuses are so related to the maxillary sinus that infection of one antrum may mean infection of all, the importance of deter-

mining the condition of the antra by skiagraphs becomes evident. A diseased root may infect the maxillary antrum, and and conversely a diseased maxillary antrum may infect an otherwise healthy root.

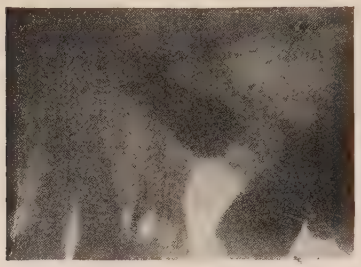


Fig. 176.

Utility of Dental Skiagraphs. — Skiagraphs are useful for the following purposes:

(1) *To indicate the position of unerupted teeth.* Figure 176 shows an impacted second bicuspid, the first molar having been removed. The light space above shows destruction of tissue. In this case there had been a discharging sinus evidently connected with the area indicated by the light space in the skiagraph.

Fig. 177.

Fig. 177A.

The indication was, of course, to remove the offending tooth, which was probably the cause of all the trouble.

(2) *Where the full number of teeth are wanting to show whether the tooth is present in the alveolus* (*Fig.* 177), *or whether the retarded eruption is due to impaction.* This skiagraph shows presence of the tooth in the alveolar tissue, delay in eruption being due to impaction. Figure 177A shows absence of permanent teeth below small deciduous incisors.

Fig. 178.

(3) *To show the position of an impacted third molar.* (*Fig.* 178.) Here the third molar is seen lying against the second molar in a horizontal position. Figure 178A represents a similar condition. Figure 179 represents a skiagraph of a dried bone specimen. It shows beautifully the presence of an impacted third molar. The white area about the roots of the third molar shows the results of tissue destruction.

Fig. 178A.

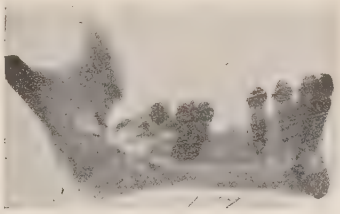


Fig. 179.

This is a specimen taken from the collection of Dr. Cryer.

(4) *To determine whether teeth are permanent or deciduous.* Figure 180 represents a deciduous tooth, with the root entirely absorbed, and the permanent tooth immediately below it.

Fig. 180.

(5) *To show conditions about the roots of implanted or replanted teeth.* Figure 181 shows a tooth which had been removed and replanted. The skiagraph taken a year after replanting shows the alveolar tissue adherent to the root and the tooth firmly rooted.

Fig. 181.

(6) *To show the existence and extent of an abscess.* In Figure 182 the light area around the roots of the molar shows the presence of an abscess.

(7) *To show whether an instrument or portion of an instrument has been left in the canal or extends beyond the apex.* Figure 183 shows the presence of a broken broach in the root canal, while Figure 184 shows two broaches extending beyond the apical foramen. Figure 185 represents a broken instrument in the alveolar process.

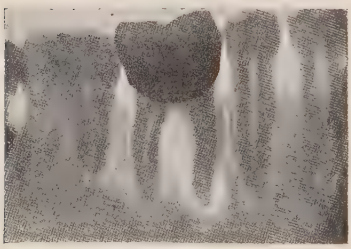


Fig. 182.

(8) *To show whether or not the canal has been completely filled, or whether the filling has protruded through the apical foramen.* In Figure 186 the gutta percha filling is shown as having passed through the apical foramen. There is also shown the evidence of lost tissue due to an alveolar abscess.

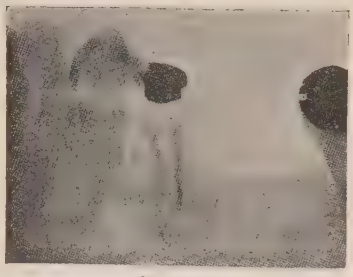


Fig. 183.

(9) *To show the existence of roots lying within the alveolar process.* In this case (*Fig.* 187) a root has been left in the alveolus after an unsuccessful extraction.

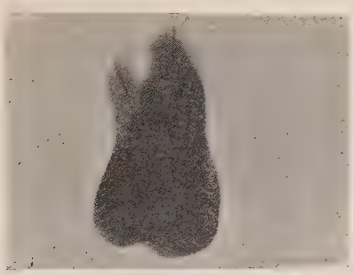


Fig. 184.

(10) *To show whether or not the roots of front teeth have been fractured as the result of a fall or blow.* Figure 188 shows a tooth in which fracture of the root was suspected. The skiagraph, however, reveals no damage to the root, with slight affection of the alveolar process. Figure 188 A shows a tooth which had been fractured by a fall, and driven into the alveolar tissues. The skiagraph clearly revealed the line

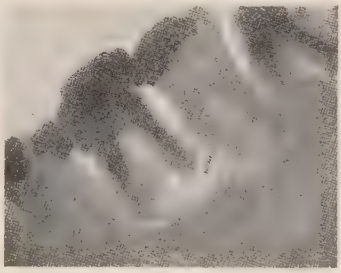


Fig. 185.

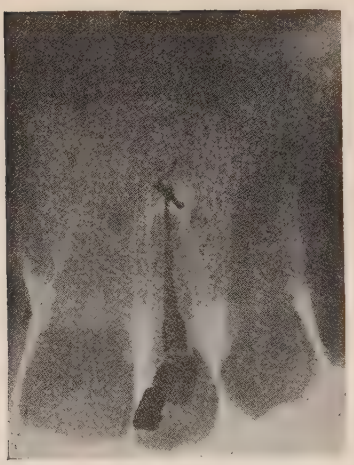


Fig. 186.

Fig. 187.

of fracture below the gingival margin. Case of Dr. C. Edmund Kells, Jr.

(11) *To indicate the presence of supernumerary teeth.* Figure 189 represents a skiagraph in which a shadow is displayed between the roots of the

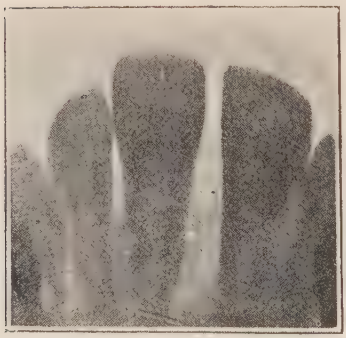


Fig. 188.

Fig. 188A.

central incisors. This is a supernumerary tooth. Figure 190 represents a well-developed supernumerary tooth. This is the small tooth between the lateral incisor and the canine.

Fig. 189.

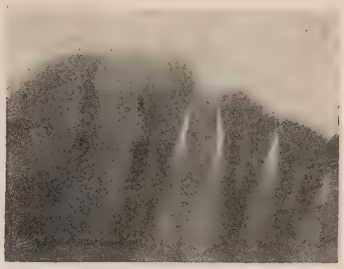


Fig. 190.

(12) *To show whether the root of a tooth is strong enough to support a crown, or serve as a support for a bridge or suitably located for that purpose.* Figure 191 is a skiagraph of a tooth which was tubed and crowned, to share with its mate the support of

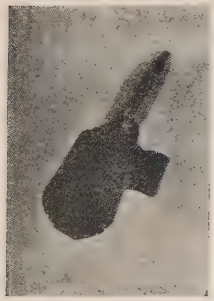


Fig. 191.

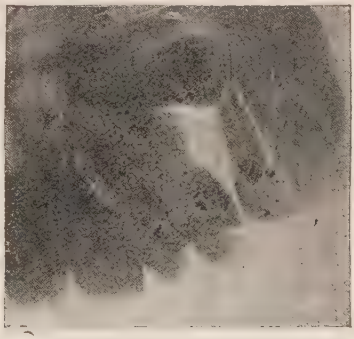


Fig. 192.

nine teeth. The experiment failed. Skiagraphy would have revealed the folly of such an attempt. Case of Dr. C. Edmund Kells, Jr.

(13) *To show whether teeth are misplaced, unerupted, or impacted.* Sometimes these three conditions will occur together, as in Figure 192.

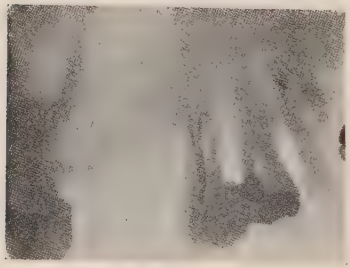


Fig. 193.

(14) *To ascertain by the introduction of a wire whether the end of the canal has been filled.* This skiagraph (*Fig.* 193) shows very clearly that the end of the root canal has not been reached. In this case Dr. Rhein, after seeing the radiograph, concluded

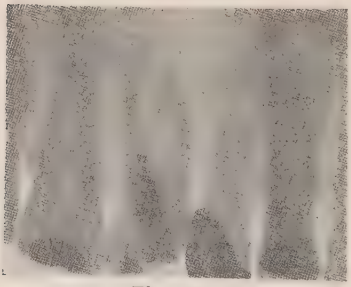


Fig. 194.

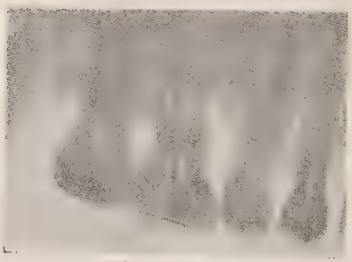


Fig. 194 A.

Fig. 195

that two more sittings would be required in order by chemical treatment to reach the end of the root. When it is considered that, according to the statement of Dr. Lewis, ninety per cent of all cases of abscess which he has skiagraphed have been due to improper or short root fillings, it would seem scarcely too much to say, that whenever there is doubt as to whether the end of the root canal has been reached, assistance should be obtained from a dental skiagraph, which will infallibly clear up all uncertainty. On the other hand, Figure 194 shows a wire which has been passed through a channel drilled between the lingual and buccal roots, and passed up into the maxillary antrum. Antral empyema is no doubt frequently caused in this manner. Figure 194A shows a wire passing to the end of the mesial buccal root, and another only a short distance into the distal buccal root. This skiagraph was taken for diagnostic purposes, and illustrates the value of employing the X-ray to determine whether or not the pulp has been thor-

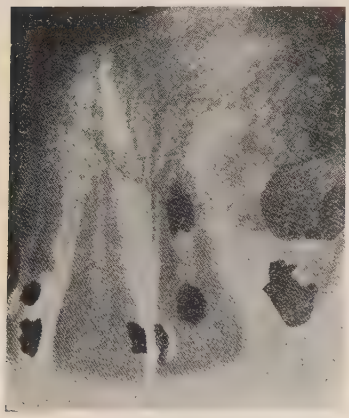


Fig. 196.

Fig. 197.

oughly removed. Figure 195 shows a skiagraph of root canals perfectly filled, the gutta percha filling running down to the apical foramen.

(15) *To show the presence of fillings which encroach upon or enter the live pulp cavity.* Where a filling is placed at right angles to the rays as they pass through the root, it can readily be determined whether there is any encroachment upon the pulp cavity. If it happens, however, to be in whole or in part in the path of the rays as they pass through the root canal, the skiagraph would not furnish conclusive evidence, since the shadow of the filling would be wholly or partially superimposed upon the shadow of the root canal. In Figure 196 are shown both conditions. In the right-hand tooth is shown a filling in the path of the rays as they pass through the root canal. Here it would be impossible to determine whether or not the filling encroached upon or entered the root canal. In the left-hand tooth, however, is seen a filling which, being in the path of the rays not passing through the root canal, is clearly seen to be a considerable and probably safe distance away.

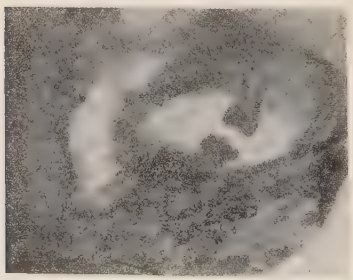


Fig. 198.

Fig. 199.

(16) *To disclose the presence of pulp stones.* Here there is some difference of opinion among dental skiagraphers, Tousey and Lewis affirming that they can be displayed, and Saterlee declaring that he has not been able to demonstrate them. Figure 197, however, clearly reveals a pulp stone.

(17) *To disclose an exostosis of the roots of a tooth.*

(18) *To disclose a necrosis of the maxillæ.*

(19) *To disclose the presence of a sarcoma.* Figure 198 represents a skiagraph of a sarcoma of the lower jaw.

(20) *To disclose a fracture of the maxillæ.* (*Fig.* 199.)

(21) *To disclose a dentigerous cyst.* (*Fig.* 200.)

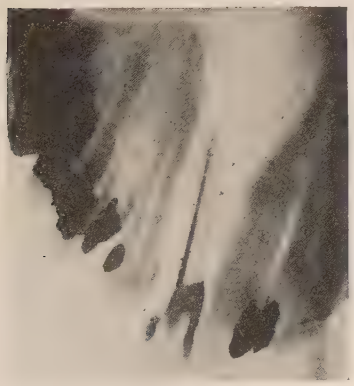


Fig. 200.

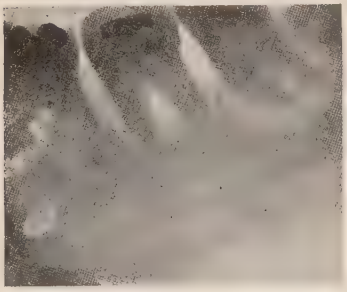


Fig. 201.

(22) *To disclose the presence of an odontoma.*

(23) *To show presence of localized deposits upon the teeth.*

(24) *To differentiate between pyorrhea alveolaris*

and conditions which simulate it. In pyorrhea there is a general alteration in the character of the alveolar tissue, the walls of the alveolar process are no longer adherent to the tooth, and a light area about the tooth indicates the change which has taken place in the structure of the peridental tissues. Cases which simulate pyorrhea are often due to deposits upon the teeth, to inflammation of the pericementum, or to the irritation of a filling upon unremoved pulp. In the latter the alveolar tissue is closely adherent to the tooth and has not undergone alteration. Figure 201 shows the appearance of the alveolar tissues affected with pyorrhea. Figure 201A shows a similar condition.

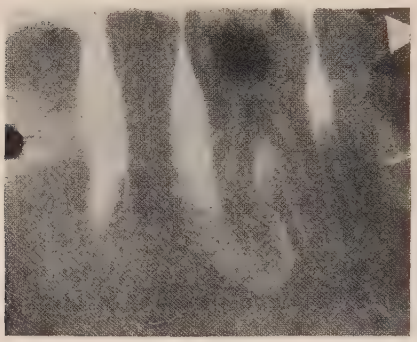


Fig. 201 A.

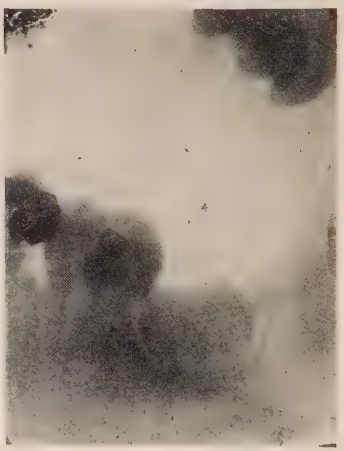


Fig. 202.

(25) *To show the cause of reflex lesions.* In all cases of obstinate neuralgia of the fifth nerve examination of the teeth should be made in order to ascertain, if possible, the presence of tumors, pulp stones, abscesses, cysts, foreign bodies, impaction,

or any other possible cause of reflex pain. Figure 202 is a skiagraph of a third molar impacted against a first molar, the second molar having been extracted. The patient suffered severely from facial neuralgia. Extraction was ordered with complete relief of pain. Case referred to the author by Dr. H. C. Spencer, of Newton, Mass.

(26) *To show destruction of the root of the tooth.* Figure 202A represents a tooth in which the root has been necrosed.

Fig. 202A.

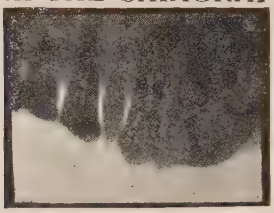
Fig. 202B

(27) *To ascertain whether there is an inflammatory condition at the root of a tooth.* In Fig. 202B the darkened condition around the root of the bicuspid indicates an overproduction of osseous tissue, due to a productive inflammation. The indication was to remove the pulp.

Record of Cases.— A careful record should be kept of all cases that require diagnosis by skiagraphy. They are highly useful for reference and are then available for reporting for the instruction of one's

colleagues in the profession. For this purpose a card of Bristol board may be employed with a blank space for pasting the print, with all useful data, *viz.* number of case, name, date, residence, age of patient, diagnosis, make of film, distance, time of exposure, tube

DENTAL SKIAGRAPH



By Dr. Herbert McIntosh

No..... Date.....

of.....

Age..... Upper..... Lower.....

Examine for.....

.....

Make of Film.....

Distance..... Time.....

.....

Tube..... Machine.....

Developer.....

.....

.....

Fig. 203.

DENTAL SKIAGRAPHS

By

Dr. HERBERT McINTOSH

No..... Date.....

M .....

Age .....

Examine for.....

.....

Make of Plate.....

Time .....

Distance.....

Developer.....

Tube.....

Machine.....

Remarks.....

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Fig. 204.

employed, generator, developer, etc. Figure 203 represents a card reduced to about one half its proper size. Figure 204 represents the envelope.

The illustrations employed in this chapter are taken partly from the author's collection, and partly from an article in the *Dental Digest* for October, 1907, by Dr. F. K. Ream, of Chicago, and a lecture by Dr. M. L. Rhein, of New York, delivered before the New Jersey State Dental Society, July, 1908. The author is also indebted to Dr. Sinclair Tousey, of New York, for a number of valuable prints.

CHAPTER XX

RADIUM

The element radium was discovered in 1898 by Madame Curie. Roentgen's discovery of the X-ray led to Becquerel's observation that uranium and its compounds had the property of affecting a photographic plate through an opaque layer of black paper. It was also found that pitchblende, an ore of uranium, had as powerful an effect as pure uranium, though containing only fifty or sixty per cent of that metal. From this circumstance Madame Curie drew the inference that pitchblende must contain a more active substance than uranium. This substance was isolated after laborious researches, and called radium because of its most characteristic property.

Classification.— Radium belongs to a class of radio-active bodies, of which uranium, thorium, polonium, and actinium are also members. The atomic weights of uranium, thorium, and radium are respectively 238, 232, and 225, or 258. The atomic weights of the remaining members of the group have not been determined. Of these metals radium is by far the most highly radio-active, being one million times as radio-active as uranium.

Physical Properties.— Radium gives off an

emanation and three kinds of rays. It also emits light and heat, and maintains itself at a higher temperature than the surrounding air.

The emanation is a heavy, luminous gas which has the property of rendering other bodies luminous which it touches. It can be liquefied by cold and traverse thin metal plates.

The rays are of three kinds, *viz.*, alpha rays, beta rays, and gamma rays. The alpha rays are positively charged particles shot off with great velocity, having about twice the size of a hydrogen atom. They have been identified as the metal helium. The beta and gamma rays are similar to those generated by a Crookes tube. Thus the beta rays are identical with the electrons reflected from the kathode of the Crookes tube, otherwise called the kathode rays, while the gamma rays are like those escaping from the Crookes tube, commonly called X-rays.

There are, however, important differences. The beta and gamma rays are produced by an inherent energy residing in the metal itself. The electrons constituting the kathode ray travel with a velocity about one tenth that of light, those constituting the beta ray move with almost the velocity of light. The beta rays, like the kathode rays, are deviated by a magnet, but with much greater difficulty. The gamma rays are much more penetrating than the X-rays, casting practically no shadows of the denser portions of the hand. The alpha ray, however, can scarcely penetrate the thinnest sheet of paper, and is very slightly deviated by the action of the magnetic field.

What are the emanations? It was said above that the alpha ray is believed to be an atom of the element helium. This has an atomic weight of four. If, however, the atom of radium weighing, we will say, 225, expels a portion of itself weighing 4, there will be left a new atom weighing 221. Now a well-known group of gases had already been discovered by the joint labors of Lord Rayleigh and Sir William Ramsey. The series runs thus: helium 4, neon 20, argon 40, krypton 82, and xenon 128. The residue left after the expulsion of the helium atom is 221, the highest member in the above group, being somewhat less than twice the weight of xenon. This is the radium emanation. It is produced steadily from radium — one atom for every alpha particle expelled.

In like manner radium belongs to the group of alkaline earths of which the other members had for a long time been known: namely, calcium 40, strontium 87, and barium 137.

We have thus the alpha ray — otherwise called helium — and its residue, a new gas, which is called the radium emanation. As already noted this emanation has the power of imparting an activity to surrounding objects, which, however, quickly decays. This emanation is deposited upon the surface of contiguous bodies as an invisible and unweighable film. The fact that the emanation decays brings to view another remarkable fact. The decay of the emanation is due to the expulsion of an atom of helium — the alpha ray — leaving a new residual atom weighing 217. This is the solid form of the radium emanation,

and is the origin of the imparted activity above referred to. This is called by Rutherford radium A. This, in like manner, expels an alpha atom, and leaves a residual atom weighing 213, which is called radium B. These changes have been elaborately studied and tabulated, until radium G has been reached as the ultimate product of disintegration. Radium F is identical with the new element polonium which is found as a constant companion of radium in pitchblende. Polonium emits alpha rays, but no other product. We therefore assume the existence of radium G, which expels neither alpha nor beta particles. Counting now the number of alpha particles or helium atoms emitted in the process, we find that they amount to five, or 20 units. Subtracting 20 units from 225, the atomic weight of radium, we have 205. As now the atomic weight of helium is slightly less than four, we see that the difference may be 207, which is the atomic weight of lead. Lead may therefore be radium G.

Radium bromide, which is the most useful salt for therapeutic purposes, occurs in small crystals or granules and has a yellowish-brown color.

Physiological Effects of Radium.— Radium produces

(1) Effects upon the skin, which may result in inflammation and ulcers.

(2) Effects upon the nervous system, which may result in paralysis and death, and

(3) Luminous effects upon the ocular apparatus of the partially blind.

Chemical Effects.— Radium liberates iodine from iodoform, produces ozone, converts corrosive sublimate into calomel, decomposes water, and affects silver salts used for photographic purposes.

Electrical Effects.— It has been shown that an insulated body containing radium will, if placed in a vacuum, become positively charged. This is due to the discharge of negative electrons.

Bactericidal Effects.— The experiments of Crookes have shown that radium has a considerable bactericidal action. In the experiments of Pfeiffer and Friedberger the micro-organisms of cholera, typhoid fever, and wool-sorter's disease were destroyed after a three days' exposure to twenty-five milligrammes of radium bromide.

Method of Application.— The salts of radium may be enclosed in a glass tube containing five or more milligrammes, which is applied for a few seconds to the area to be treated. They may also be enclosed in capsules covered with mica. Another method is to place them in a button, the front of which is made of aluminium 1–100 of an inch in thickness, and the back of lead of equal thickness. The button is supplied with a screw thread which permits it to be placed in

Fig. 205.

holders adapted to the situation of the lesion to be treated.

Still another method is to enclose the radium salts in a small metallic capsule with a front of quartz. This is also provided with a thread for attachment to suitable handles. Figure 205 represents a set of containers and handles for the administration of radium treatments.

Measurement of Radio-Activity.— For purposes of measurement the radio-activity of uranium is taken as unity. Thus pure radium bromide has a radio-activity one million, eight hundred thousand times as great as that of uranium. Most specimens of radium bromide are mixed with barium bromide. A good sample of radium bromide should produce phosphorescence on a barium-platino cyanide screen through several copper coins.

Cost of Radium Compounds.— The cost of a grain of gold is about five cents. The cost of an equal quantity of radium bromide is about $5,000. It thus appears that the salt of radium most suitable for therapeutic purposes is about one hundred thousand times as expensive as gold. Specimens of radium containing barium bromide are less expensive but also much less effective. The price of a pure sample is, therefore, almost prohibitive for private practitioners, and largely confines the use of this most interesting substance to public institutions which can afford to make large expenditures for therapeutic and experimental purposes.

CHAPTER XXI

PHYSICS OF LIGHT

Definition. Light is an energy which by its action upon the retina excites the sensation of vision. This manifestly inadequate definition will serve as an introduction to the subject. Its defects will appear as its properties are analyzed.

Theory as to its Propagation. Two theories have been proposed to explain the phenomena of light. The first in the order of development is the *corpuscular or emissive theory.* This assumes that a luminous object has the power of throwing off particles of light as a bullet is discharged from a gun.

The second is the *undulatory theory*, which presupposes the existence of a medium called the ether, in which a wave motion is produced by the luminous body. There is no progressive motion of the particles themselves, but an oscillation which is transverse to the line of propagation, just as a wave can be made to advance along a rope every portion of which runs successively upon either side of an imaginary line drawn between its ends. The latter theory serves very well to explain the various phenomena of light and is generally accepted as a working hypothesis. Various discoveries of recent years have,

however, served to revive interest in the corpuscular theory, and to a certain extent to rehabilitate it. A certain blending of the two theories furnishes the best aid to the scientific imagination in the effort to explain the phenomena of light.

The extensive employment of light for therapeutic purposes makes it imperative that a brief review of the physics of light be presented at this point. While necessarily inadequate and touching only upon those principles absolutely indispensable to an intelligent use of light energy for therapeutic purposes, it must include a cursory explanation of reflection, lenses, refraction, spectrum analysis, and diffraction.

In every homogeneous medium light is propagated in a straight line. The velocity of light was first deduced by the Danish astonomer Römer from observations upon the eclipse of one of Jupiter's satellites. This velocity is about 190,000 miles per second.

Laws of Reflected Light. When light is reflected it is found (1) that the angle of reflection is equal to the angle of incidence; (2) that the incident and reflected rays are both in the same plane, which is perpendicular to the reflecting surface.

Mirrors. Mirrors are bodies with polished surfaces which show by reflection objects presented to them. According to their shape they may be *plane, spherical, parabolic, conical, etc.*

Plane Mirrors. The image seen in a plane mirror is a virtual image. This may be illustrated

by Figure 206, in which A is a point in an object from which rays pass to a mirror F G and are reflected at B and C to the eye D. The image which is seen at A is obtained by the prolongation of the rays which enter the eye, and seems to be behind the mirror. This is a virtual image, as it has no real existence at the point where it seems to be.

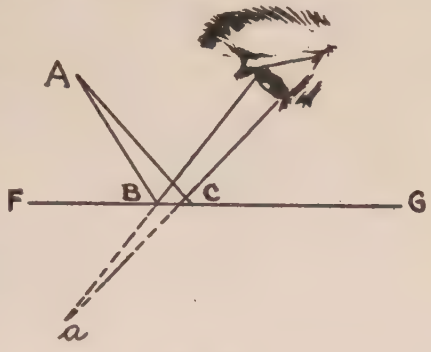


Fig. 206.

Spherical Mirrors. Spherical mirrors have a spherical curvature. They may be produced by the revolution of an arc about a radius. (*Fig.* 207.) They are concave or convex according as the reflection is from the concave or convex surface. The center of curvature is also the principal focus when the reflected object is placed at C. Where, however, the rays come from an infinite distance the principal focus is midway between the center of curvature and the mirror. The aperture is the angle of F C G, formed by joining the center of curvature with the extremities of the mirror. The principal axis is formed by a line passing through the center of curvature and the center of the mirror C A. A secondary axis is formed by a line passing through the center of curvature C and any other point in the

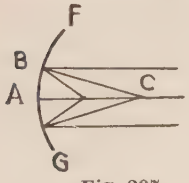


Fig. 207.

mirror. Images reflected from mirrors may be virtual or real.

Virtual Image. If the object A B be placed between the center of curvature and the mirror the reflected rays from a given point, as A, will be divergent and will seem to come from behind the mirror. In this case the object is virtual, erect, and larger than the object.

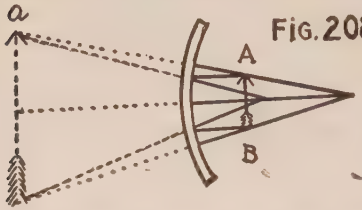


Fig. 208

Real Image. This may be illustrated by Figure 209, in which G is a concave mirror whose center of curvature is at C. A B is an arrow placed beyond the center of curvature. In order to obtain an image of any part, as A, draw two lines, one along the secondary axis A D and another A F parallel to the principal axis. A F is reflected to F *a* and A D is reflected along its own path. The point of intersection will be the real image *a*. In like manner the point B will produce the image *b*. We then have at *a b* a real inverted image of A B which is smaller than the object and placed between the center of curvature and the principal focus. A familiar illustration of a real imageisthe reflection obtained from the concave surface of a dessert spoon which lies upon the table. Thus the image of a chandelier or other object above the table may be

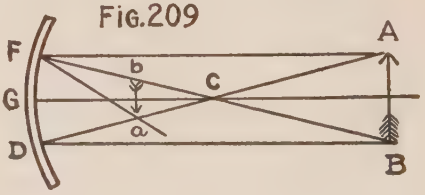
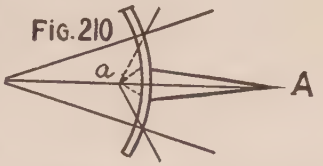


Fig. 209

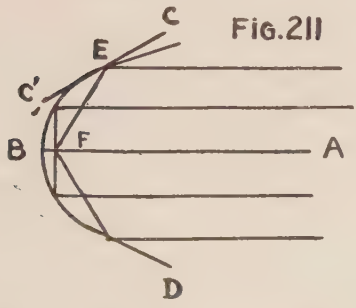
observed projected in space between the eye of the observer and the reflecting surface. This is a real, inverted and reduced image.

Convex Mirrors. The images obtained from convex mirrors are virtual images, as illustrated in Figure 210 where the dotted lines show the continuation of the divergent rays behind the reflecting surface. The virtual image of the point A is *a*.



The focal length of a concave mirror is half the length of the radius of curvature, and is readily determined when sunlight is available by placing the mirror so that the incident rays are parallel to the principal axis. The image of the sun is then found by moving a glass screen back and forth until the reflection is seen with the greatest distinctness. This is the principal focus.

Application. Concave spherical mirrors are used for searchlights, an electric light or some other source of illumination being placed at the principal focus. Parabolic mirrors are theoretically to be preferred to spherical mirrors. The latter are also extensively used for therapeutic purposes.



Parabolic Mirrors. In concave spherical

mirrors parallel rays falling upon the reflecting surface converge only approximately at the principal focus; and conversely, when a source of light is placed at the principal focus the reflected rays are only approximately parallel to the principal axis.

A parabolic mirror is produced by the revolution of the arc of a parabola, as C D (*Fig.* 211) about its axis A B. Such a mirror is harder to construct than a spherical mirror, but it is free from the defect of divergence of luminous rays as above described.

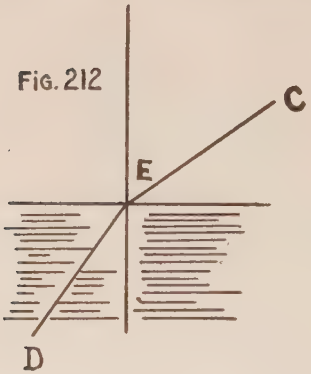


Fig. 212

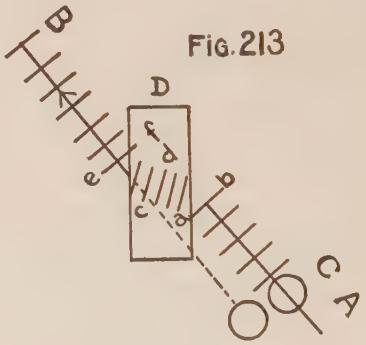


Fig. 213

Thus if a line B E be drawn from the focus F to any point in the surface of the mirror E and a line drawn parallel to the principal axis, it will make equal angles with a tangent C C′ at that point. Here all parallel rays falling upon the mirror are converged after reflection at the principal focus, and conversely a luminous object placed in the principal focus will send its reflected rays parallel to the principal axis.

Refraction. Refraction is the bending which rays of light undergo in passing obliquely from one

medium to another, as from air to water. (*Fig.* 212.) Thus when the incident ray C E strikes the water at E it is refracted and takes the direction E D. In order to understand this phenomenon we may employ the illustration in Figure 213, in which A B is a series of wave fronts leaving an object A and reaching the eye at B through a rectangular piece of glass D. Now it has been discovered that light is retarded in passing through denser media. Therefore when the wave front *a b* reaches the glass it is retarded at *a*, but continues to advance at its previous rate at *b*. When it has entered the prism it therefore takes the position *c d*. When it passes out of the denser medium at *c* its rate is increased and it then takes the position *e f*. After that it advances evenly until it reaches the eye at B.

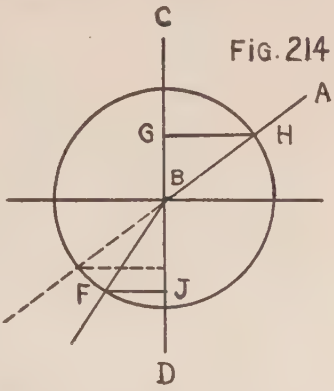
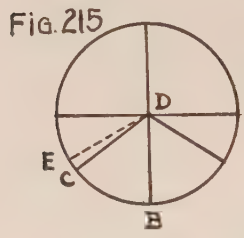


FIG. 214

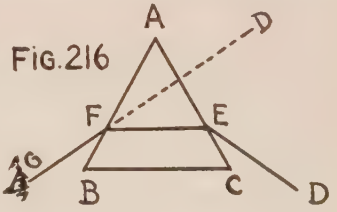
Index of Refraction. By this is meant the relation which the angle of incidence bears to the angle of refraction. This relation has been found to be uniform for the same media whatever the angle may be. Thus in Figure 214, A B C is the angle of incidence and D B F is the angle of refraction. The lines G H and F J, drawn from the perpendicular to the intersection of the radii, B H and B F, are called sines. Now the sines G H and F J will always be in the same ratio for air and water, whatever may be

the angle of the incident and refracted rays. Thus it is found that the refractive index for air and water is 4–3; for air and glass is 3–2. These represent also the ratios of velocities in the respective media.

Critical Angle. Total Reflection. In Figure 215 C D is an incident ray passing through water and emerging into air. It enters at such an angle that the refracted ray is parallel to the surface of the water. The angle C D B is called the critical angle. An incident ray E D outside the critical angle will not emerge from the water and is totally reflected. Total reflection, therefore, occurs when the rays in the more refractive medium fall at an angle greater than the critical angle.



Prisms. A prism is a transparent medium enclosed between two plane faces inclined to each other. The edge of the prism is the intersection of the two faces. A principal section is a section perpendicular to the edge, as in Figure 216, in which A is the summit and B C the base. From our study of refraction it is easy to determine the path of rays in a prism. Thus the ray D E will take the path E F in the prism and F G upon emerging, and the object will be seen as if coming from D′. An object seen through a prism appears deflected toward its summit.



Lenses. These are transparent media bounded

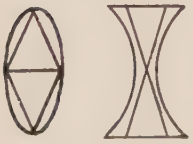
by two curved surfaces, or one plane and the other curved. These may be divided into two classes, *viz.*, converging and diverging. In the first class are found double convex, plano-convex, and concavo-convex lenses. In the second class are found double concave, plano-concave, and convexo-concave lenses. (*Fig.* 217.)

A little reflection will show that a double convex lens is made up of two prisms joined at their bases and a double concave lens of two prisms joined at their edges, thus: (*Fig.* 218.) In accordance with the laws of refraction already learned it becomes easy to determine the path of rays traversing these media. Such refracting media enter into various apparatus employed for diagnostic and therapeutic work, and it is highly important that physicians should understand the physics underlying their use.

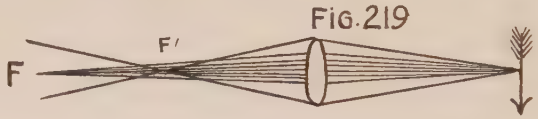
Fig. 217

Spherical Aberration. Where the aperture of a lens does not exceed ten degrees to twelve degrees, incident rays are brought together at a single point. In lenses with a larger aperture (*Fig.* 219) the incident rays which traverse the edges are brought together at a point nearer the lens, as F′. This injures the sharpness and definition of the picture, and is called spherical aberration. This error may be corrected by using diaphragms, called stops, which cut off the rays near

FIG 218

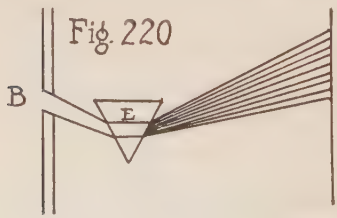


the edges of the lens. It may be diminished by the use of two lenses of double focal length which are placed a little distance apart. Thus the aperture is



reduced and it is not necessary to cut off the edges, and the convergence is as great as that produced by one lens.

Dispersion. Thus far we have considered refraction in prisms without an inevitable accompaniment if white light be employed. If a beam of white light be passed through a prism it will be found not only that the beam will be refracted but that it will be decomposed into several kinds of light. (*Fig.* 220.) To this the name dispersion is given. Thus if a beam of light be allowed to pass into a dark chamber through a small aperture, following Newton's original experiment, and fall upon a prism, it will after refraction be found to have undergone a marked change. It is no longer white light, but is made up of a variety of colors which pass by gradations into one another. This is called the solar spectrum, and is made up of red, orange, yellow, green, blue, indigo, and violet. These colors are simple, that is to say, they cannot be split up into more elementary colors by further decomposition. They are of unequal *refrangibility*,



red having the least and violet the greatest. They occupy unequal portions of the spectrum, violet having the greatest extent and orange the least. While it is customary to say that there are seven primary colors, there is as a matter of fact an infinite number of primary colors in the spectrum which pass into one another by insensible gradations.

PROPERTIES OF THE SPECTRUM.— The properties of the spectrum are (*a*) heating, (*b*) luminous, and (*c*) chemical.

(*a*) *Heating Effects.* The heating effects of the spectrum reside principally in the red and infra-red areas, though the results obtained vary with the nature of the prism employed, a water prism producing greater calorific effects in the yellow zone. Langley's researches into the spectrum revealed an invisible heat spectrum extending to a distance twenty times the length of the visible spectrum below the red zone, the largest wave measuring .005 millimeter.

(*b*) *Luminous Effects.* Light in the yellow zone has the greatest intensity, in the violet zone the least.

(*c*) *Chemical Properties.* Silver chloride blackens under the influence of sunlight. This chemical action is found to be most energetic at the upper end of the spectrum and to extend into the invisible region, called the ultra violet region, which lies above the visible spectrum. The length of the spectrum beyond the violet has not been determined.

Doubtless there are vibrations extending from the lowest ascertained limit of the ultra violet region across an unexplored field to the region of the X-ray

vibrations. Ultra violet energy is to a large degree absorbed by the atmosphere. Even the chemical portion of the visible spectrum is considerably reduced in the neighborhood of cities.

Fig. 221

From what we have thus far learned of ethereal vibrations we may construct the following scale, in which no attempt is made to represent the relative areas occupied by the various vibrations. (*Fig.* 221.)

In this scale while the chemical activity is manifested chiefly by the green, indigo, blue, violet, and ultra violet portions of the spectrum, luminous activity by the yellow and orange portions, and heat activity by the red and infra-red, yet these properties are manifested in a degree by the whole spectrum.

Dark Lines of the Solar Spectrum. If a pencil of solar rays be admitted to a dark room through a

narrow slit, and examined at a distance of three or four yards by means of a flint prism with the edge turned parallel to the slit, a great number of dark lines situated at unequal intervals will be found traversing the spectrum. Fraunhofer was the first to map the most marked of these lines, which he indicated by the letters A a, B.C.D.E.b.F.G.H. They are called Fraunhofer's lines, and among other uses are landmarks for determination of the refractive index of transparent substances.

Bright Line Spectra. If a platinum wire be immersed in common salt and heated in the flame of a Bunsen burner and viewed through a prism, as already described, a yellow band without any other color will appear in exactly the same position as Fraunhofer's dark line D.

Continuous Spectra. If a platinum wire be brought to a white heat, it will yield a continuous spectrum containing all of the primary colors. We have thus described three kinds of spectra, (*a*) bright line spectra, (*b*) continuous spectra, and (*c*) absorption spectra, as where the spectrum of the sunlight is viewed.

Spectroscope. While these experiments may be performed with a simple prism more satisfactory results may be obtained by means of a direct vision spectroscope. (*Fig. 222.*) This is an arrangement of prisms of crown and flint glass which produce dispersion without refraction of light.

We have thus seen that the spectrum of incandescent solid bodies is continuous, the spectrum of

incandescent gases is made up of bright bands or lines, and the spectrum of the sun is characterized by dark lines. If a beam of light from an arc lamp is passed through the flame of a Bunsen burner which has been made yellow by sodium chloride and is viewed by a spectroscope, it will be found that a dark band is now seen in place of the yellow sodium band. The explanation of this interesting phenomenon is that, though the light is transmitted through the dark band of the spectrum, yet it is so feeble in comparison with the other parts of the spectrum that it seems dark by contrast. Thus the vapors of different metals quench the same rays as

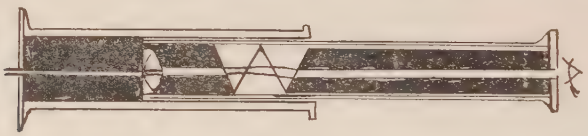


Fig. 222.

they themselves emit. Thus when looking at the solar spectrum and finding a dark band in place of the yellow sodium band, we are justified in concluding that this metal exists in the photosphere of the sun in the form of a luminous incandescent gas. By an application of this method it has been found that a large number of terrestrial substances exist in the luminous atmosphere of the sun and fixed stars. By spectrum analysis the elements caesium, rubidium, thallium, and indium were discovered.

Diffraction. When light passes over the edge of a body or traverses a small aperture, the rays appear to become bent and penetrate into the shadow,

This phenomenon is of great interest inasmuch as it affords a proof of the undulatory theory of light, and furnishes a method for computing the wave lengths and the number of vibrations per second corresponding to each primary color. It has been ascertained that the wave length of red light is .000605 millimeters, of violet light is .000404 millimeter

Using the formula $N = \frac{v}{l}$ in which v stands for the velocity of light per second and l for the wave length, we ascertain that the number of vibrations per second corresponding to the dark line B is four hundred and thirty-six billions per second, and for H in the violet is seven hundred and fifty-seven billions. In like manner the number of oscillations for the intermediate rays is readily calculated.

Ultra Violet Rays. Glass effectually cuts off the passage of the ultra violet rays. Quartz, however, permits the higher frequencies up to wave lengths of two hundred millionths of a millimeter to pass without absorption. In like manner the atmosphere absorbs a large part of the ultra violet energy of the spectrum, which increases in amount in proportion to the altitude of the observer. Both water and glass entirely absorb the invisible frequencies of the spectrum. It is therefore evident that when the operator is seeking to use the invisible energies of the spectrum he must avoid any medium like glass or water which interferes with their passage. Even a thin veil of smoke will effectually cut off the ultra violet ray. While, however, glass cuts off the higher frequencies it readily permits the visible spectrum to pass without absorption.

Ultra Violet Light Rendered Visible by Fluorescence. Just as the X-ray is invisible but is capable of manifesting its presence by fluorescence, so the ultra violet ray may be rendered visible by fluorescence. This results from the fact that certain substances are capable of absorbing energy at one wavelength and emitting it at another. By introducing a plate of uranium glass into the eye piece of a prism spectroscope ultra violet rays from the source of illumination at once become visible.

Transmission of Ultra Violet Rays. With respect to the transmission of ultra violet rays there are four classes of substances.

(1) Those that are transparent throughout the ultra violet region, as sodium chloride.

(2) Those that are opaque throughout the ultra violet region, as window glass from wave lengths .0000325 millimeter.

(3) Those whose opacity increases with decrease of wave lengths, as white mica.

(4) Those which exhibit absorption bands, as iodine in carbon disulphide.

Properties of Ultra Violet Rays. (1) They produce chemical changes in silver salts.

(2) They cause certain substances, as willemite, to fluoresce.

(3) They positively electrify metals, as polished zinc.

(4) They decrease the resistance of an air gap upon which they shine.

(5) They discharge negatively electrified bodies.

(6) They can be reflected, refracted, and polarized.

(7) They do not ordinarily traverse tissues unless the latter are dehematized. Though they cannot traverse even a thin sheet of paper they readily penetrate rock salt.

(8) They produce a green fluorescence in willemite and a blue phosphorescence in polysulphide of calcium.

(9) They produce nuclei for the condensation of vapor in moist air.

(10) They are bactericidal.

Testing Presence of Ultra Violet Rays. This is best done by means of an electroscope. When exposed to sunlight the electrically charged leaf will not leak, but when connected to a piece of polished zinc upon which the ultra violet rays are permitted to shine it rapidly loses its charge.

The X-ray and Ultra Violet Rays.—It is probable that the X-ray vibration is an ultra violet frequency of short wave length and irregular rhythm. It causes rapid leaking of the electroscope whether it be positively or negatively charged. It ionizes the air much more rapidly than the ultra violet ray. It tears apart chemical compounds possessing a high degree of cohesion, acting much more powerfully than the ultra violet frequencies. It produces a more active effect upon the dermis than the epidermis and acts destructively upon hemaglobin.

CHAPTER XXII

PHYSIOLOGY OF LIGHT

It is a familiar effect of light that exposure of the skin to the rays of the sun or an electric arc will produce erythema. A few minutes' exposure of the unprotected shoulders and arms to the sunlight upon the sea beach in the summer time produces in many instances an unexpectedly rapid and painful result. This proceeds from two causes. First, at the seaside there is less foreign material in the atmosphere to absorb the highly chemical frequencies of the sun's rays, and secondly, reflection from the water and sand enhances the radiant energy of the sun's rays. We may therefore say that:

(1) *Light energy may produce an irritant effect upon the skin.*

In the summer, or in the winter when snow is upon the ground, the exposed portions of the skin becomes dark. This is due to an increased development of the pigment cells in the *rete mucosa.* In tropical races there is a permanent darkening of the skin, due to the same cause. From these facts we may conclude that:

(2) *Light energy increases pigmentation of the skin.*

It is a familiar observation that under exposure to the sun's rays the sweat glands become more active. This can be shown to be due to the chemical rays of the spectrum as well as the thermal. Therefore:

(3) *Light energy increases the energy of the sweat glands.*

If a part of the body is exposed to the rays proceeding from the sun or an electric arc, it will be noted that there is dilatation of the superficial blood vessels. Therefore:

(4) *Light energy produces superficial hyperemia, and as a determination of blood to the surface of the body cannot take place without its withdrawal from the interior, it follows that when large areas of the body are exposed to light energy, there must be a depletion of the viscera.*

There is ample proof that light energy is destructive of bacterial life outside of the body, and that this bacterial action is chiefly characteristic of the ultra violet rays. The proof of its destructive action in living tissue is not equally positive. That it does, however, exert an inhibitory effect upon the growth of bacteria, probably through its influence upon the nutritive *media* in which they live, and by the development of oxygen which is fatal to the continued existence of anaërobic microbes is equally positive. While, therefore, the chemical frequencies of light energy are most destructive to bacterial life *outside* the body or upon surfaces where great penetration is not required, they exert an inhibitory effect upon bacterial life in living tissue, because their absorption

by the red blood corpuscles increases the oxidizing power of the latter, and thus renders bacterial growth and multiplication more difficult. This result is doubtless aided by an increase in tissue resistance due to general improvement in health. We may therefore conclude, that:

(5) *Light energy exerts an inhibitory effect upon bacterial growth in living tissue. This conclusion finds confirmation in its clinical applications.*

Molschott, Selmi, and Piacentini have shown that dogs, hens, pigeons, and frogs eliminate less carbon dioxide in the dark than in the light. This follows from the observation of Quincke that blood, muscle, kidneys, liver, etc., absorb more oxygen in the light than in the dark. The increased absorption of oxygen would necessarily quicken the combustion of the tissues and enlarge the elimination of carbon dioxide. We may therefore safely conclude, that:

(6) *Light energy increases the elimination of carbon dioxide and the activity of the process of combustion.*

In like manner it has been shown by S. Goodnew, that human beings and animals excrete more urine, urea, and chlorides when continuously exposed to daylight than when remaining in the dark. We may therefore conclude that:

(7) *Light energy increases urinary elimination.*

When the nude body is exposed to light energy there is a rise in temperature and an acceleration of both pulse and respiration. These observations of Goodnew have repeatedly obtained clinical confirma-

tion. While these results are not absolutely uniform, they occur with sufficient regularity to warrant the conclusion, that:

(8) *Light energy tends to raise the normal temperature and accelerate pulse and respiration.*

It should be remarked, however, that these results are obtained from the whole spectrum, colored rays tending to lower the pulse, particularly the violet.

Dogel and Jegerow found when the eye was exposed to the green region of the spectrum, that the circulation of both men and dogs was modified. In like manner P. Bert noted that a chameleon deprived of sight in one eye became pale in color on the corresponding side of the body. Thus we may infer, that:

(9) *Light energy may produce motor excitation.*

Sudden exposure to bright light will produce violent sneezing. This is a reflex from the sensory fibres of the trigeminus distributed to the Schneiderian membrane. Hence we may conclude, that:

(10) *Light energy may produce reflexes.*

There is an extensive series of observations tending to show the varied effects upon the nervous system produced by colored lights. Thus while notable exceptions might occur in individual cases, it is generally true that the lower frequencies, as red, tend to produce excitement, the higher frequencies, as violet, depression, with intermediate effects ranging between these extremes. Hence we may conclude that the colored rays of the spectrum.

(11) *May produce marked psychical impressions.*

As a result of an extensive series of experiments

carefully conducted by Pansini at the Institute of Physiology of the Royal University, Naples, reported in the *Revue Internationale d'Electrotherapie et de Radiographie*, October, 1903, it was shown, that:

(12) *Blue light increases the energy and resistance of voluntary muscles.*

These results correspond with those obtained by Dr. G. V. Poore and Dr. Capriati in their studies upon the effects of the electrical currents upon muscular tissues. (*Chapter* IX, *Part I.*)

It is to be noted that these results are peculiar to blue light, white light having no influence, and red light exerting a depressing effect. Pansini's monograph is illustrated by ergograms showing graphically the results of the tests employed.

Upon the question as to whether light has any effect upon the internal viscera, there is diversity of opinion. The ultra violet rays are largely absorbed by the skin, but as a photographic plate placed upon the posterior surface of the body shows the chemical effect of the rays thrown upon the anterior surface, it may safely be inferred that the chemical rays of the visible spectrum penetrate the body. Equally there can be no question as to penetrating power of the lower frequencies of the spectrum. Energy that penetrates the tissues performs work. It has already been noted that the effect of light upon the blood is to increase its oxidizing property. To do this is to heighten metabolism and promote tissue exchanges. We may then provisionally infer, that:

(13) *Light energy tends to improve metabolism.*

The portions of the spectrum possessing greatest therapeutic value are the invisible and visible chemical frequencies. A large amount of evidence has been produced to show that the first effect of irradiation by blue light is to produce vasoconstriction. The resulting anemia tends to produce analgesia, which frequently extends to anesthesia. Thus it may be safely affirmed, that:

(14) *Blue light tends to produce analgesia, frequently passing into anesthesia.*

Finsen's studies in smallpox tend to prove that the chemical rays of the spectrum have a marked influence in promoting suppuration, and that when these rays are excluded by placing the patient in a dark room, or a room illuminated only by red light, the disease does not advance to the stage of suppuration, with its concomitant increase of fever. Historically considered, these observations antedated by many years the researches of Finsen, since both in England and on the continent it had been customary to protect patients suffering from smallpox from diffused daylight. Similar observations in relation to the unfavorable action of the chemical frequencies of the spectrum in the exanthemata have been made with reference to measles, scarlet fever, erysipelas, and other eruptive diseases. We may then conclude, that:

(15) *The chemical frequencies exert an unfavorable influence upon the exanthemata.*

It has been found clinically that patients exposed to the action of the X-ray are protected against derma-

titis by a subsequent exposure to white light. It thus appears, that:

(16) *To some extent the effects of the X-ray and light are antagonistic.*

CHAPTER XXIII

METHODS OF APPLICATION

The following methods may be employed for the application of light treatment:

(1) Sun baths; (2) electric arc baths; (3) incandescent arc baths; (4) the concentrated energy of the visible frequencies of the solar spectrum; (5) the concentrated energy of the electric light; (6) the concentrated energy of the incandescent light; (7) the energy of the visible chemical frequencies — blue light treatment; (8) the energy of the visible thermal frequencies — red light treatment; (9) the energy of the ultra violet frequencies — ultra violet light treatment; (10) vacuum tube discharges; (11) radioactivity of radium; (12) fluorescence.

(1) *Sun Baths.* The important relation which sunlight bears to health need not be dwelt upon. Enough has been presented already in discussing the physics and physiology of light to make out a strong case in favor of using the rays of the sun for the promotion of bodily health. Solaria, or sun baths, have always been employed to some extent among ancient as well as modern peoples. There are certain conditions which, however, reduce the effectiveness of this method of treatment. The first is that the ultra

violet rays of the sun are to a very great degree cut off by their passage through the atmosphere to elevations near the level of the sea, especially in the neighborhood of cities, where floating dust serves to absorb them in still greater measure. In the second place, there is a great reduction in the volume of light as the sun approaches the winter solstice, and even in the summer season there is only a relatively small portion of the day when sun baths are possible. A third condition which limits the availability of this method is the presence of clouds and vapors which act as a screen to the passage of the rays of the sun.

In the summer time the nude body may be exposed daily at the seashore with advantage to health. Where this is not possible scanty bathing suits may be worn. Rooms may be so constructed as to admit sunlight where patients may be placed so as to receive the direct radiation from the sun. Here the window glass will shut out such ultra violet rays as have not already been filtered out by the atmosphere, but will not exclude the chemical frequencies of the visible spectrum. A green screen may be used or glasses may be worn by patients to protect the eyes, and in general such precautions may be taken as to time of exposure and protection of the head against insolation, and such subsequent treatment may be employed in the way of hydrotherapy and massage as the condition of each patient may require.

(2) *The Electric Arc Bath.* Inasmuch as the sun, especially in northern climates, is for long periods of the time obscured, it becomes interesting to discover

whether light artificially created may not be invoked to supply this defect. This energy is admirably supplied in the electric arc, which is always available where electricity is commercially furnished for illuminating purposes. While it lacks the inspiring accompaniments of solar exposure in the summer time at the seashore, it has nevertheless a range of energy which exceeds that of sunlight, for, as already explained, the transit of the sun's rays through the enormous envelope of terrestrial atmosphere deprives them of a large portion of their ultra violet frequencies. These are much more active in the electric arc. All the physiological effects, therefore, which have been collated in the previous chapter may be expected from this form of light administration. It should be remembered, however, that it is not primarily a form of heat administration. In the electric arc bath the temperature of the cabinet is not materially raised. It is in a true sense a light treatment, in which the results obtained are not confused with the effects which flow from mere diaphoresis.

There is a slight generation of gases by the electric arc. While they may not have been determined with absolute accuracy, it is probable that as in the ordinary combustion of carbon there is first the production of carbonic monoxide, which is highly poisonous. This is, however, by oxidation immediately converted into carbon dioxide, which, though not in itself poisonous, is destructive to life through exclusion of oxygen. There is also a production of nitrous oxide gases. There may be a slight generation of

hydrocyanic acid, and also ozone, though the latter statement is denied. The quantity of these gases is not large, and so far as their effect is discernible, they are distinctly advantageous to the patient, as proved in actual practice. The power of disinfection is a noticeable attribute of the gases generated by the electric arc.

Arc Light Cabinet. An arc light cabinet can readily be constructed in a part of the operator's office, and if built for one patient should be of a convenient size for the reception of a cot upon which he may recline. It should be lined with zinc or other metal to guard against the danger of fire. This is painted white and finished with white enamel. An arc light is suspended at each end of the cabinet, the carbons being placed at an angle of about forty-five

Fig. 222A.

degrees in order that the crater of the positive pole may act as a reflector upon the body of the patient. For this reason in therapeutic applications of the arc light it is important to place the positive pole above the negative, since about 85 per cent of the energy of the arc light proceeds from the positive pole and only 10 per cent from the negative, the ultra violet arc furnishing the remainder. This arrangement permits a downward reflection of the light energy which the lamp produces. There may be two windows, one near the top of the cabinet for ventilation, and another for observation, or there may be openings in the roof to permit the escape of convective currents. The patient reclines upon the cot and is divested of his clothing. The treatment may occupy an hour or less, according to circumstances. On the alternating current mains the lamps will ordinarily furnish about two thousand candlepower apiece, and use about ten amperes at a pressure of fifty volts. The cabinet is supplied with a rheostat. The patient should be provided with colored glasses, and also with a screen for hands and face if he desires to avoid tanning.

Figure 222A represents the arc light bath cabinet employed by the author. The dimensions are approximately six and one half feet in length, nine feet in height, and two and one half feet in width. It is lined with zinc and provided with a folding cot and mattress. It has an observation window in the door and trap doors in the top for ventilation. It is furnished with two Bogue lamps of 5,000 candlepower each. A fine mesh brass wire screen with pan pro-

tects the patient from falling particles of incandescent carbon. The lamps may be inclined at an angle of forty-five degrees when deemed desirable, though the volume of light is so great that the perpendicular position equals most demands. The rheostat is shown upon the upper right-hand corner. The photograph displays on the right the incandescent bath employed by the author and on the left a shower bath.

Incandescent Light Baths. These are primarily thermal baths inasmuch as the total luminous efficiency of an incandescent lamp is only five per cent

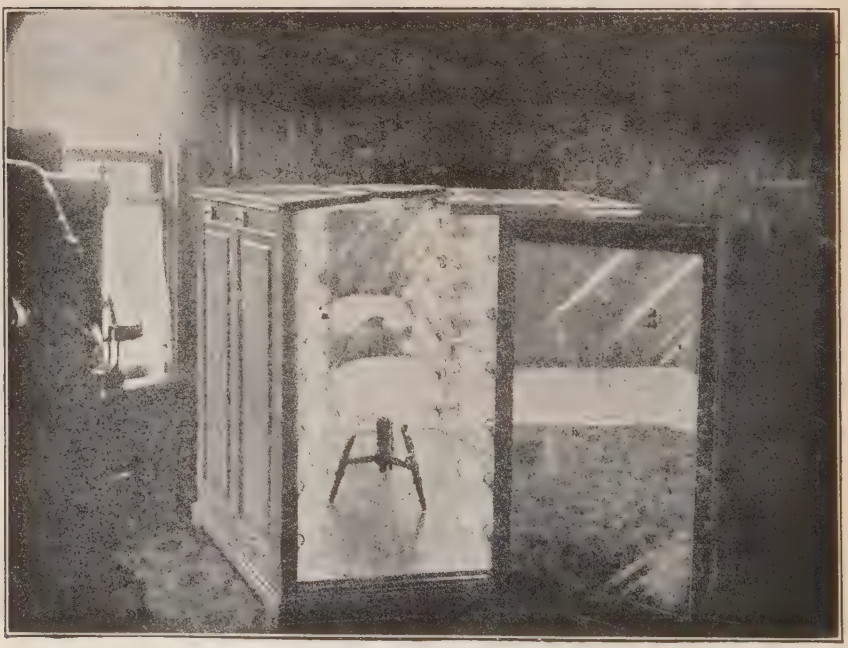


Fig. 223.

of the whole output. The spectrum of an incandescent lamp contains all the visible frequencies from violet to red. The chemical frequencies are, however, poor, while the red, yellow, and green are rich. While, therefore, the chemical frequencies constitute a small part of the total output of an incandescent lamp, yet by increasing the number of lamps in an incandescent cabinet the aggregate of chemical effect can be greatly increased. Its chemical efficiency is less than that of the electric arc, both because of the inferiority of its visible chemical spectrum and because the enclosing bulb entirely cuts off the ultra violet frequencies. It is also inferior to sunlight. It must be noted, however, that the heat of an incandescent light cabinet differs from the heat of an unilluminated cabinet, since the latter supplies convective heat while the former furnishes radiant heat.

Nernst Lamps. These furnish a light richer in chemical frequencies than incandescent lamps. Since they do not require a glass covering they also furnish ultra violet energy. The percentage of efficiency is about twice that of incandescent bulbs.

To Kellogg belongs the credit of introducing incandescent light baths. In 1894 he presented a paper before the American Electro-Therapeutic Association, containing a resumé of his work with incandescent bath cabinets.

(3) *Incandescent Light Cabinets.* These may be arranged either for the sitting or recumbent position. Where the patient reclines the couch is constructed of glass so that the whole body may be illum-

inated, and the bulbs, one hundred or more, arranged in such a manner as to furnish a complete irradiation of the superficies. The energy is reflected and multiplied by polished mirrors. The head remains outside the cabinet. For the sitting posture an octagonal box is provided, constructed of or lined with steel, and so arranged as to permit easy ingress and egress. (*Fig.* 223.)

Incandescent Baths Superior to Hot Air or Vapor Baths. As already indicated, an incandescent light bath is superior to a hot air or vapor bath, because the former produces radiant heat, the latter convective heat. Radiant heat penetrates to the interior of the body, and produces its effect in a much shorter time than convective heat. There is, moreover, the effect arising from the action of the visible chemical rays, and that produced by the transformation of the lower frequencies into heat. Doubtless the red rays, quite apart from their thermal efficiency, produce a useful effect upon the tissues.

A remarkable characteristic of the incandescent light cabinet is the prompt effect produced upon the sweat glands. This is much more rapid than that produced by hot air or vapor baths, and is due to the effect of radiant heat upon the peripheral nerve endings.

(4) *The Concentrated Energy of the Visible Frequencies of the Solar Spectrum.* In order to obtain the concentrated energy of the sun either concave or convex mirrors may be employed. Since the heat of the sun would then become intolerable it becomes

necessary to filter out the lower frequencies by means of a solution of copper sulphate or a screen of blue glass.

(*a*) *Convex Lens.* This is the ordinary burning glass with which most of us have been familiar since childhood. An aqueous solution of sulphate of copper or methylene blue may be contained within the lens, or a blue glass screen may be used to filter out the frequencies below the blue. It must be remembered, however, that the use of glass also effectually excludes the ultra violet rays, even where quartz lenses are used, since water or glass filters must be used to cut off the thermal frequencies.

(*b*) *Concave Mirrors.* These concentrate light more effectively for therapeutic purposes than do lenses. Similarly water or glass filters may be used for cutting off the lower frequencies. This method of treating disease is scarcely practicable in such climatic conditions as exist in the neighborhood of Boston or other Eastern cities. It therefore becomes necessary to resort to other methods for the production of light.

(5) *Concentrated Energy of the Electric Light.* This concentration is effected by the use of (*a*) reflective mirrors and (*b*) focal senses. In some apparatus, as in the marine searchlight, the former method is employed, in other types, as Finsen's, the latter. Some, as the Lortet et Genoud lamp, employ both. Primarily these types of apparatus have been developed for the treatment of skin diseases, as, for example, Finsen's heavy and expensive apparatus. Some of

them, however, as the marine searchlight and the solar lamp (*Chapter VII, Figs.* 51 and 53) may be successfully employed for systemic conditions. In the treatment of all conditions where a deeply penetrating effect is not required, as in many kinds of skin diseases, the apparatus is so constructed as to permit its close application to the surface, as in the treatment of lupus. This necessitates the cutting off of the thermal rays, which may be accomplished by the use of a water jacket, as in the Finsen apparatus. Inasmuch as the pre-eminently useful frequencies for skin lesions are the chemical and more especially the ultra violet, it is customary to provide compression lenses which are transparent to the ultra violet frequencies, and which by pressure upon the area to be treated render it anemic. Ice serves admirably to produce anemia by cold and pressure, and is also transparent to the ultra violet ray. Rock salt permits the passage of the ultra violet frequencies, but does not exclude the thermal. Quartz is transparent to the ultra violet ray. Adrenalin chloride may be used for the purpose of rendering the skin anemic and may be introduced into the tissues by phoresis.

Reference has already been made to some types of light apparatus in Chapter VII. The great prototype is furnished in the Finsen apparatus, which concentrates the arc light from an eighty ampere current by means of two sets of lenses placed inside of each of four telescopic tubes by which the divergent rays of the arc light are first rendered parallel, and then caused to converge upon the area to be treated. The

heat is filtered out by a water chamber which is kept cool by water circulating through a water jacket. Inasmuch as the residual light is still too warm, Finsen designed a hollow compressor of quartz which

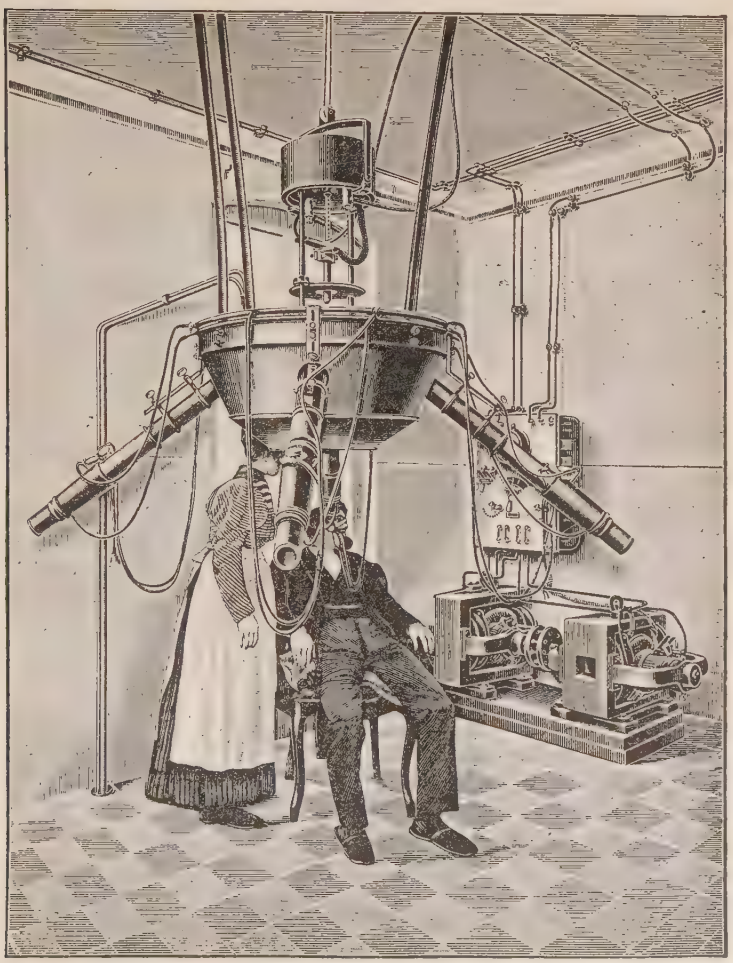


Fig. 224.

he filled with water and connected with a system of afferent and efferent pipes, thus providing for a constant circulation of cool water. (*Fig.* 224.) As a substitute for this elaborate and expensive apparatus, the Lortet et Genoud lamp was invented, of which the London Hospital lamp in England and the Victor-Finsen lamp in this country are imitations. (*Chapter VII, Fig.* 52.) They are much less expensive, use much less current, and in general produce satisfactory results. Experiments have proved that these lamps are quite equal or superior to the Finsen lamp in their output of ultra violet energy. The use of glass lenses in the Finsen apparatus cuts off the energy of the ultra violet frequencies. They are not, however, equal to the Finsen apparatus in the power of penetration of the deeper tissues, illustrating the value of high amperages and large carbons where deep effects are to be produced.

Marine Searchlight. This type of light (*Chapter VII, Fig.* 53) may be used at a distance of from seven to fifteen feet from the patient, and owing to the fact that it furnishes the whole energy of the spectrum is to be preferred where it can be used without exciting too much discomfort. In those cases where the heat is not well borne blue glass screens may be interposed. In this lamp reflecting mirrors of the Mangin type are employed. A twenty-five ampere lamp when adjusted on short focus will illuminate objects at a distance of one mile and a quarter. This lamp may also be adjusted for actual contact with the skin if desired.

Iron Electrode Lamp. The spectrum of iron is rich in ultra violet frequencies. For this reason the positive carbon pencil of the arc light, sometimes the negative also, is cored with iron. The high actinic quality of the iron spectrum has led to the introduction of lamps in which the arc is formed by passing between iron pencils. The first lamp of this kind was devised by Dr. Bang, Finsen's assistant. The electrodes are cooled by water, and the lamp is provided

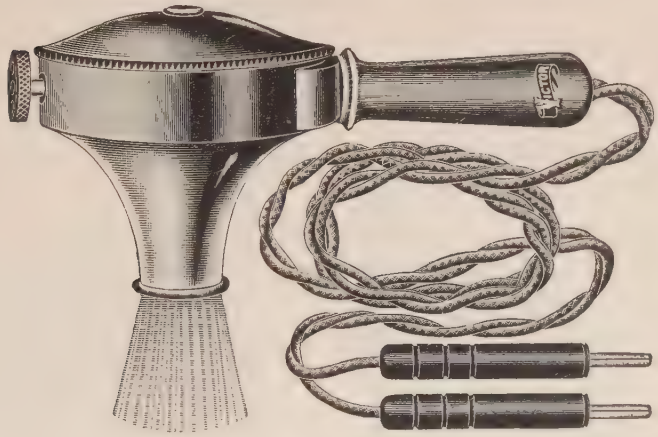


Fig. 225.

with a quartz plate which acts as a compressor and permits the free passage of the ultra violet ray. This lamp is useful for the treatment of superficial lesions, but it lacks the penetration of carbon lamps having a larger amperage.

Figure 225 illustrates an iron electrode lamp made by the Victor Electric Company.

(6) *Concentrated Energy of the Incandescent Lamp.* This differs from that already described under the head of incandescent light baths chiefly in the fact of localization, for there is a degree of concentration in both methods, though more in the latter than the former.

For directing the energy of the incandescent light upon particular areas a variety of mechanisms may be employed, consisting of reflecting surfaces which direct the light of one or more incandescent bulbs upon the affected parts. In Chapter VII, Part I (*Fig.* 50) is shown a small hand lamp used for therapeutic purposes. Larger lamps, however, of five hundred candlepower, supported by a bracket from the ceiling or wall, are very useful for the administration of this

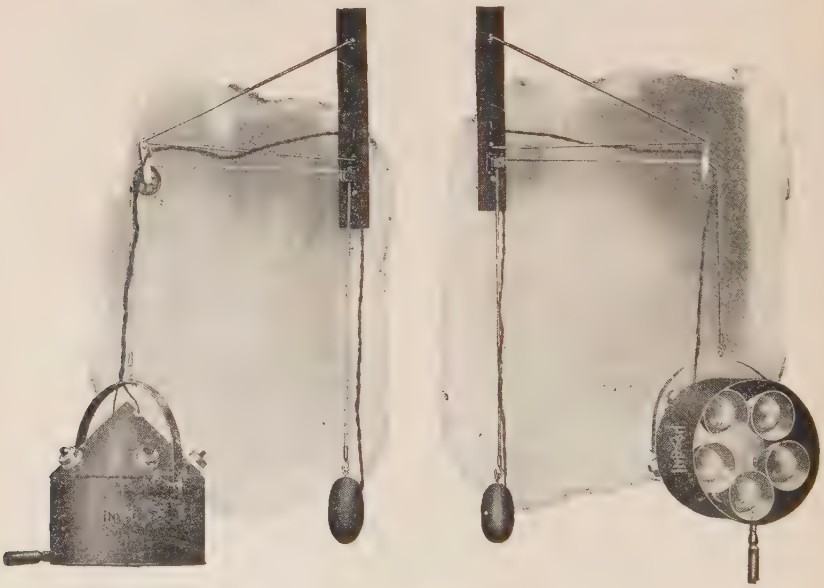


Fig. 226.

form of light energy. (*Fig.* 226.) They have the great advantage of ease of manipulation, and furnish a large amount of energy.

While inferior to the electric arc lamp in the output of visible and invisible chemical frequencies, which are the most useful portions of the spectrum for therapeutic purposes, the incandescent lamp is yet valuable for its thermal effects and also for the penetrating frequencies of the visible chemical spectrum. Doubtless also there is therapeutic value proceeding from the light frequencies quite apart from the radiant heat effects into which they are measureably transformed.

(7) *The Energy of the Visible Chemical Frequencies. The Blue Light Treatment.* Nearly forty years ago Dr. S. Pancoast, of Philadelphia, embodied his views upon the subject of light treatment in a curious book entitled "Blue and Red Light." Mingled with much recondite learning derived from the Kabbala are shrewd observations to which modern research gives support. While the orthodox medical mind of that day refused to be impressed by the demonstrations of the author, there was excited for a time a marked interest in the subject of light treatment largely among the laity, and rooms with blue or red glass windows were fitted up in different parts of the country for the treatment of disease.

The physiological effects of blue light treatment having been collated in Chapter XXII, it remains to describe the apparatus by which blue light treatment may be effected.

The lower frequencies of the light spectrum are usually filtered out by a screen made of strips of blue glass. A screen thus constructed is preferable to a screen of blue glass in one piece, because a crack in a single strip is not communicated to its neighbors. Unfortunately the higher frequencies are also excluded by this arrangement, but since they are lacking in penetration, their exclusion is not to be greatly regretted.

Where greater penetration is desired two concave glasses containing a solution of alum are substituted for the blue glass screen, and the area to be treated is placed in the focus of the lens. Such an arrangement may be used with any source of light in which the visible chemical frequencies are sufficiently rich, as solar, arc, or incandescent light.

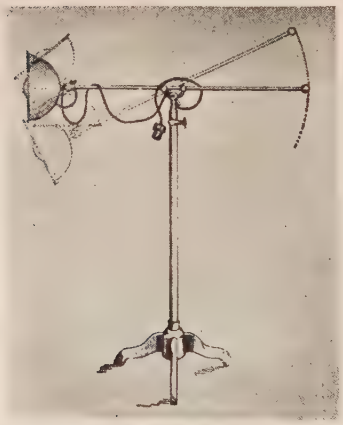


Fig. 227.

Dr. A. W. Minin, of Petersburg, has constructed a lamp which bears his name. (*Fig.* 227.) This is a cheap and portable apparatus, consisting of a stand supporting an arm terminated by the socket of an electric lamp. Into this socket may be put an incandescent lamp of sixteen, thirty-two, or fifty candle-power with a blue glass bulb. Each lamp is provided with a reflector. A ground bulb is also furnished for frictional applications to the part.

While much less efficient than an arc light provided with a screen for filtering out the thermal rays, it yet performs a useful service where the former arrangement is not available.

(8) *The Energy of the Visible Thermal Frequencies. The red light treatment.* This treatment consists in filtering the rays of the sun, electric light, incandescent light, or other lights through red screens. These may be of any material, provided they entirely suppress the chemical frequencies of the spectrum. The theories as to the effects produced by the red light treatment are three. The first assumes that the beneficial effects of this treatment in the diseases to which it is applicable are due entirely to the exclusion of the chemical frequencies of the spectrum, the second that they are due to the specific action of the red frequencies, and the third that they are due to the exclusion of the chemical frequencies and the specific action of the red.

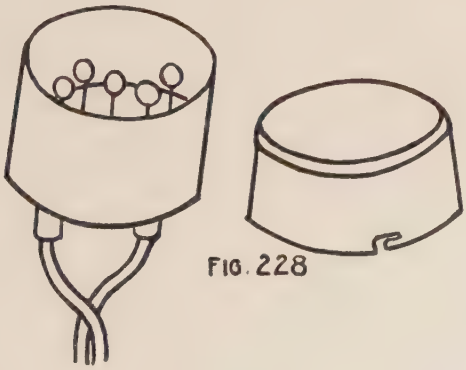


FIG. 228

(9) *The Energy of the Ultra Violet Frequencies. Ultra Violet Light Treatment.* Hitherto we have discussed several methods of treatment in which ultra violet rays are produced, as in sun baths, electric arc baths, or in the concentrated energy of the sun and the arc electric light.

In these methods, however, the ultra violet rays are associated with the other portions of the spectrum. We shall here speak of methods of producing ultra violet energy with as little association with the other frequencies as possible.

The Electric Spark. This supplies the ultra violet frequencies with great richness, when furnished from metallic terminals of iron, copper, aluminium, or mercury.

Görl Apparatus. When the operator has only a static machine he may use the Görl apparatus. This consists of five aluminium balls arranged like the letter S, along which the current passes, producing sparks as it traverses the air space between the balls. (*Fig.* 228.) This lamp may be placed in shunt with the Leyden jars of the static machine, or it may be connected directly with the sliding rods. Iron may be substituted for aluminium, and a quartz compressor provided for the purpose of concentrating the light and rendering the parts anemic. The Piffard ultra violet ray lamp involves the principle of the Görl lamp. The same apparatus may be employed in connection with induction coils, and in England is used with some modifications under the name of St. Bartholemew's Induction Coil Arc lamp.

Condenser Spark Gap Lamp. It is possible to obtain from high frequency apparatus of the Tesla type sparks very rich in ultra violet light. After passing through a step-up transformer, the current is carried through a series of mica plate condensers and next across iron or steel terminals. The essential principles of the Görl lamp are illustrated in these condenser lamps. (*Fig.* 229.)

(10) *Vacuum Tube Discharges.* Vacuum tubes are of interest at this point because they generate light energy. This is chiefly the energy of the visible

Fig. 229.

chemical spectrum, the ultra violet rays being excluded by the glass of which the tube is made. This fact should be attentively observed, since the uninstructed purchaser is often misled into believing that the vacuum tube is a source of ultra violet light.

Vacuum tubes are of two kinds: (*a*) those having leading in wires and (*b*) those without. The former furnish a more energetic electrical action; the latter a richer light spectrum.

The negative terminal of a coil or static machine is the richer in chemical energy. This acts with much

promptness, even upon photographic paper that is not highly sensitive. Therefore the tube should be connected with the negative terminal of the source of electrical supply. A deep penetration of light energy, however, is not to be expected from vacuum tubes. Their role is rather in superficial and recent inflammations.

(10) *Radio-Activity of Radium.* A brief consideration of radium may be found in Chapter XX.

Spinthariscope. The light-giving property of radium is illustrated by the spinthariscope of Crookes. This is an instrument in which a small quantity of radium bromide is placed in front of a screen of phosphorescent sulphide of zinc. The discharge of luminous particles upon the screen is viewed through a magnifying glass. This is an illustration of phosphorescence as well as radio-activity, since the discharge of alpha particles is rendered visible by the use of a phosphorescent screen.

Solution of the Emanations in Cocoanut Charcoal. Much experimentation is now being carried on to determine the therapeutic value of the radium emanations. Dr. Wm. J. Morton, of New York, has spent much time in the study of these radiations and has endeavored to obtain watery solutions of them. These he obtains by immersing fifty to one hundred pounds of pitchblende in a vessel of water. The water acquires a measure of radio-activity equal to one tenth to one half of a disc of uranium oxide taken as a standard. This he dispenses to patients who are taking radium or X-ray treatment. The solution is,

however, very unstable, manifesting radio-activity for only a few hours and entirely disappearing in a few days.

Recently Professor Rutherford has discovered that if a stream of air which has been passed over a salt of radium is carried into a tube containing cocoa-nut charcoal, the emanation from the radium is after a time completely absorbed by the charcoal.

Acting upon this hint Shober* has undertaken elaborate experiments, and found that charcoal thus treated acquires a very high degree of radio-activity. Thus, while water in which pitchblende had been immersed had a radio-activity of only one tenth of a disc of uranium oxide taken as a standard, charcoal treated as above described had a radio-activity one hundred and sixty times as great. Moreover, while the radio-activity of water disappears in a few days, the radio-activity of charcoal continues for a much longer period, and is thirteen times as great as a uranium oxide disc for a period of thirteen days.

It is an interesting fact that a quantity of radium thus treated presently loses its radio-active emanation, and must be permitted to rest for about ten to fourteen days before it has recovered sufficiently to give off its usual amount of emanation.

Dr. Shober states that he has been able to obtain from one charge sufficient charcoal of one hundred and forty activity to fill five small test tubes, each containing enough to last a patient fourteen days, the

**Journal of the American Medical Association*, J. D. Shober, M.D., August 21, 1909.

dose being as much as would cover a dime taken three times daily.

It is believed that the value of many mineral springs depends not upon the salts in solution, but upon the radio-active emanations which they have absorbed. These, however, speedily disappear upon removal from their natural sources. Attempts to reproduce the virtues of these waters by artificially dissolving the same salts are failures, because these virtues reside in the emanations and not in the salts contained in solution. It is believed that the method of manufacture above described is an important advance in the application of radium to the cure of disease.

What the relative degree of curative power possessed by the different radio-active manifestations of this remarkable metal is has, of course, not been determined. Nor is there any present means of determining it, since the emanation contains the same rays as are given off by radium itself.

Charcoal prepared as above described may be made into ointments and placed upon the surface of rodent ulcers, patches of eczema, or psoriasis, lupus, or other areas of cutaneous disturbance. It may be administered internally for gastric or duodenal ulcer, for tubercular peritonitis, or for gastric or intestinal carcinoma. Its effect in neuritis and arteriosclerosis should also be determined.

(12) *Fluorescence.* This is the property which some bodies possess of becoming self-luminous after exposure to the direct rays of the sun. It derives its

name from fluor spar, which is a substance in which this property was discovered. This phenomenon is due to the fact that some substances like fluor spar have the property of absorbing light at one rate of frequency and emitting it at another, usually a lower frequency. A fluorescent body, therefore, may be looked upon as a transformer of radiant energy. Among the substances which manifest this property in a marked degree is quinine sulphate. All portions of the spectrum are capable of producing fluorescence, though this phenomenon manifests itself more powerfully at the upper end of the spectrum in the ultra violet region, and is a property also of the Roentgen and Becquerel rays.

Fluorescence belongs not only to the mineral kingdom, but manifests itself also in the animal and vegetable kingdoms. Thus certain low forms of life, like the infusoria, are capable of fluorescing. In like manner chlorophyl, the green coloring matter of plants, is a fluorescent body, and blood as far back as 1866 was found to possess this property. In this power possessed by blood and lymph to fluoresce under the action of light may be found the key to the remarkable influence which radiant energy has upon animal life. Thus, for example, it has been found that the normal fluorescence of the blood is absent in malaria. It may, therefore, be assumed that inasmuch as the sulphate of quinine is a fluorescent substance it acts as a specific in this disease by restoring the normal fluorescence to the blood.

PART TWO

THERAPEUTICS

THERAPEUTICS

Introduction

In the following discussion of therapeutical procedures it is not assumed that electricity is the only method deserving of confidence. In some conditions it is undoubtedly the best; in others it is to be regarded as an adjuvant, while in still others its usefulness may be seriously doubted. It does not supersede hygiene, dietetics, or a rational method of living. While it frequently in some methods of administration makes a powerful impression upon the imagination, and thus imparts useful suggestions of returning health, it shares in this respect with all other therapeutic remedies which the physician employs.

The previous pages have endeavored to show by a discussion of the physics and physiology of electricity that the results which flow from the application of physical agencies to the treatment of disease are necessary and inevitable and are not due to empiricism on the one hand or chiefly to psychic impression on the other. Many of the physiological effects of electric treatment are demonstrable, and capable of reproduction by independent operators working under the same conditions everywhere. The results are quite as positive as those which are obtained by well-

established and clinical procedures in drug medication. A vast amount of research work, however, must yet be done in order to settle many questions in the comparatively untilled fields of electrical, light, and radio-active therapy. In our own country too little work unfortunately is being done along the lines of laboratory research. Among physicians who are enlarging their therapeutic resources by the introduction of apparatus, treatments are too often administered very largely upon a purely empirical basis, without a careful study of the reasons why one method should be employed rather than another. The great need is for a more thoroughly scientific method in the employment of physical therapeutics. It may fairly be said that the makers of apparatus display far greater skill in the manufacture of the tools which they supply to physicians than the latter employ in their use of them. More than this, the manufacturer usually possesses a much better comprehension of the physics underlying the energies which he studies than the physician. There are, of course, notable exceptions to this statement. It is, however, unfortunately true of the rank and file of the profession.

It is not urged that electricity be employed to the exclusion of clinical procedures which have earned the confidence of the profession. In many instances it will still be desirable to continue to use them. To the wise physician all methods of cure are open, and he is at liberty to select such weapons as, in any given case, may effect with the greatest promptness, efficiency, and satisfaction to the patient the purpose

which he has in view. He is not, therefore, primarily an electro-therapeutist because he has enlarged his armamentarium by the introduction of this comparatively new weapon, but he is still the *physician*, who is the progressive student of nature, or better still, the *doctor*, who teaches his patient a wise observance of natural law.

CHAPTER I

DISEASES OF WOMEN

URETHRAL CARUNCLE.— When pedunculated this growth may readily be removed by means of a hot wire snare after thorough anesthetization by means of four per cent cocaine carried into the tissues by anodal diffusion. If the growth is sessile, it may be detached by negative electrolysis, a flat needle being carried through the base of the tumor close to its attachment until it is wholly removed. If after these procedures the area of attachment seems somewhat elevated, it may be touched by a copper electrode attached to the positive pole. The characteristic green color immediately appears from infiltration of the tissues with the salts of copper. Small currents ranging from two to eight milliamperes are sufficient for these procedures. The electrical treatment of these annoying growths has many advantages over surgery, among which may be noted the absence of hemorrhage and the avoidance of general anesthesia.

AMENORRHEA.— *Direct Current.* The patient should lie upon a large pad about twelve by twenty inches square. A smaller pad should be carried alternately from the epigastrium to the hypogastrium, and a current of from 50 to 75 milliamperes carried

through the abdominal and pelvic plexuses. This may be followed by an induced current treatment from the primary coil. This treatment, combined with the usual hygienic and medicinal regimen, will usually restore the suspended function.

The foregoing method may be employed when, as in the case of virgins, it is deemed undesirable to make a vaginal examination. The following method is much more efficient in restoring normal menstruation.

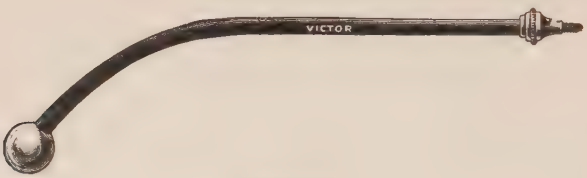


Fig. 230.

A suitable electrode (*Fig.* 230), being a copper ball upon an insulated stem, is covered with well-moistened cotton and placed in the posterior vault of the vagina. It is then attached to the negative pole of a constant current battery and a current of from twenty to thirty milliamperes passed for ten minutes three times weekly for the three weeks preceding menstrual flow. The positive pole is a large abdominal pad. A still more active effect may be secured by the use of a uterine instead of vaginal electrode. (*Fig.* 231.)

Electric Bath. Less efficient, but also useful in restoring the catamenia, is the electric bath.

Induced Currents. Dr. Mundé regards induced

currents, carried into the uterus by means of a suitable electrode, of great value in restoring menstruation. Two or three treatments a week, lasting from twenty to thirty minutes, may be continued for a number of months. He has proved this treatment of particular value in obese women.

Scanty Menstruation.— *Direct and Induced Currents.* Where there is a reduction of the monthly flow in mature women, the introduction of the negative electrode into the uterus, as above described, is

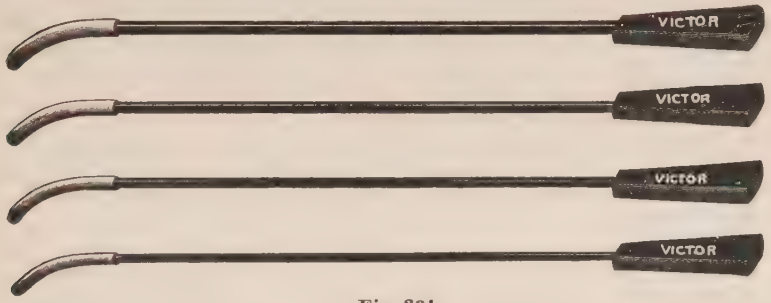


Fig. 231.

attended with the happiest results. This may be alternated with the induced current, the cerebral fulness and discomfort characteristic of this condition quickly subsiding with the restoration of the menstrual function. The other methods of treatment suggested under amenorrhea are applicable.

Dysmenorrhea.— We shall not attempt to conform closely to the usual classification of dysmenorrhea into obstructive, congestive, neuralgic, ovarian, and membranous, since these types tend more or less to overlap. Where malpositions produce obstruction to the flow of the menstrual fluid, they must,

of course, be first corrected. When metritis and endometritis are the etiological factors they must likewise receive attention. In like manner ovarian involvement may share largely in the production of painful menstruation and demand previous treatment.

We shall therefore consider at this point those types of dysmenorrhea which are due: (*a*) to an undeveloped or so-called infantile uterus, characterized by a long conical cervix and a small fundus about as large as an English walnut and almost lacking in muscle fiber; (*b*) to atresia or stenosis of the cervical canal; (*c*) to the expulsion of an organized membrane at the menstrual period; and (*d*) to excessive congestion at the menstrual epoch.

The conditions associated with the classical types of dysmenorrhea are properly treated under other heads.

Infantile Uterus.— *Direct and Induced Currents.* A small metal olive mounted upon an insulated staff (*Fig.* 232) is attached to the negative pole of a constant current battery, the positive pole being attached to a large pad placed upon the abdomen, a current of about five or ten milliamperes being allowed to pass. This enters readily, under the influence of the current, which renders the tissues soft and slippery. The direct current is now turned off and, for the purpose of developing the muscular tissue of the fundus, a slowly interrupted induced current is switched on. Larger olives are successively introduced by the assistance of the direct current when necessary, and employed to furnish induced current

massage to the undeveloped uterus. When the canal is sufficiently enlarged, the direct current is no longer employed. By such methods a uterus may be quickly enlarged from a depth of one and one half to two and one half inches.

Atresia or Stenosis.— *Direct Current.* Where atresia or stenosis of the cervical canal exists, producing a real obstruction to the passage of the menstrual fluid, the treatment is directed toward the removal of the stricture. That such a narrowing of the passage exists apart from the flexions of the uterus has been denied, inasmuch as it has been shown that

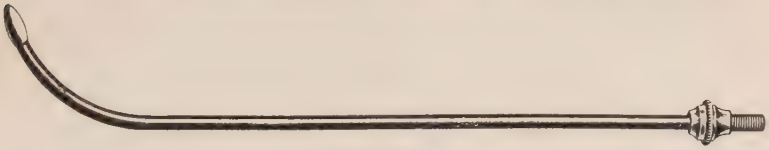


Fig 232.

during the pains of a so-called obstructive dysmenorrhea the uterine sound could be easily passed. When, however, such narrowings occur from whatever cause, they may readily be relieved by the introduction of properly graduated sounds attached to the negative pole of the direct current battery. The caliber of the canal having first been ascertained, an olive-pointed electrode (*Fig.* 232) about two sizes larger is introduced and pushed against the resisting area. A current of about five milliamperes may be employed, when the electrode will pass through the ring almost without pressure. The operation may be repeated in five or six days with a larger electrode.

The indifferent pole is a small pad upon the abdomen.

Membranous Dysmenorrhea.— *Direct Current.* The indication here is to soften the hardened membrane so that it may not be thrown off as a large mass, but by a softening process undergo a gradual degeneration. This may be accomplished by introducing an intra-uterine sound having a metal tip about one and one quarter inches in length mounted upon an insulated staff. (*Fig.* 231.) This is attached to the negative pole of a constant current battery, the positive to an abdominal pad. A current of thirty milliamperes may be employed and continued for from eight to ten minutes. The treatments may be given twice a week, until the arrival of the next menstrual period.

Congestive Dysmenorrhea.— *Static Wave Current.* For a congestive dysmenorrhea due to a simple excess of physiological activity at the menstrual epoch, or to associated inflammations of the parametria, the wave current may be employed daily for a period of twenty minutes during the whole intermenstrual period, by means of a rectal electrode or an abdominal electrode over the pubic region, or a vaginal electrode in the posterior fornix. The spark gaps may measure from two to four or eight inches.

Induced Current. As an alternative treatment for this condition an induced current may be carried through the pelvic organs by means of abdominal and sacral pads. In the judgment of the author the former treatment is far more efficacious.

Malpositions of the Uterus.— Here two conditions present themselves: (1) Where there is fixation of the uterus; (2) Where there is mobility of the uterus.

In the first condition the indication is to break up adhesions. If adhesions are present with inflammation, the latter should first be removed either by the static wave current as above described, or by means of the positive electrode consisting of a metal ball mounted upon an insulated staff. (*Fig.* 230.) The ball is covered with cotton and introduced into the vagina and placed against the mass of adhesions. A current of twenty-five or thirty milliamperes is allowed to flow for ten minutes three times weekly. When the inflammation has disappeared, the vaginal electrode is connected with the negative pole and the treatment continued as before. When the adhesions have been dissolved by the solvent action of the negative pole, a slowly interrupted induced current is employed for a period of five or ten minutes, for the purpose of removing the exudates. The next step is the introduction of an intra-uterine electrode (*Fig.* 231), which is first used to reposit the uterus and next to carry a slowly interrupted induced current for the purpose of massaging the uterine muscles and ligaments. The uterus is then held in place by the introduction of a wool tampon saturated with boroglyceride, which is permitted to remain until the next treatment.

In the second condition, where the uterus is mobile, the necessity for dissolving adhesions does not

exist, and the second part of the above treatment only is demanded.

Prolapsus Uteri.—Here the static wave current may first be employed for relief of inflammation, as described above. It is better, however, to place the cervix in a uterine cup electrode (*Fig.* 233), lift the uterus and employ a slowly interrupted current for a period of from ten to fifteen minutes. A retaining tampon should be introduced and allowed to remain until the next treatment two days later.

Fig. 233.

Chronic Endometritis.—This condition, whether corporeal or cervical, is readily corrected by cupric-phoresis.

Corporeal Endometritis. Cupric Phoresis. An intra-uterine copper electrode is introduced into the uterus (*Fig.* 231) and attached to the positive pole of a direct current battery. A current strength of from thirty to fifty milliamperes is allowed to flow for ten minutes. The cupric salts deposited in the mucous membranes are highly antiseptic. If, therefore, the endometritis is septic in origin it is speedily cured, because there is no fissure or crevice to which these

salts are not carried. If it is hemorrhagic in character the astringent quality of the positive pole quickly acts as a corrective. If the endometritis is fungoid in nature the repressive and astringent effect of the cupric salts quickly restores the mucous membrane to its normal condition.

Cervical Endometritis. Cupric Phoresis. A simple catarrh of the cervix which does not depend for its existence or continuance upon a flexion or other associated conditions may be readily cured in the same manner. The thick mucous plug, so difficult to dissolve, is quickly coagulated by the acid developed at the positive pole. After a treatment lasting from five to ten minutes with a current strength of from thirty to forty milliamperes, upon removal of the electrode, it is found not only that the mucous plug is effectually removed, but that the cervical mucous membrane has been practically curetted and the cupric salts deposited throughout the tissues. After each treatment the exudate will be found to have been reduced. The cure is rapid and complete.

Chronic Metritis.— *Cupric Phoresis.* The treatment of this condition is somewhat similar to that described above. If the metritis is due to a septic cause, the introduction of an intra-uterine copper electrode (*Fig.* 231) attached to the positive pole will quickly destroy pyogenic organisms. Hemorrhagic metritis is rapidly corrected by the same method.

Induced Current. Where normal involution after parturition has been delayed, the slowly interrupted induced current applied to the interior of the uterus is efficient.

Direct Current. On the other hand, where there is hyperplasia of the uterus without discharge, a condition sequential to metritis with discharge, the indication is to stimulate contraction and regenerate muscular fibrils. This is best accomplished by the negative pole of the direct current assisted by slow induced currents.

Senile Metritis. — *Cupric Phoresis.* The opposite condition, to which attention is directed by Skene in his "Medical Gynecology," namely, senile or atrophic metritis, which is most rebellious to medical treatment, may be successfully treated by the use of the copper intra-uterine electrode attached to the positive pole as above described. The odor is quickly corrected and the cure effected in a relatively short time.

Salpingitis.— *Cupric Phoresis.* Apostoli has pointed out that the mere passage of a sound will often cause a recrudescence of inflammation of a pyogenic cavity. This furnishes a diagnostic test of the existence of a pus tube, which is often invaluable. When, therefore, satisfactory evidence has been presented of the existence of a pyosalpinx, tentative treatment may be begun by the use of a ball copper electrode (*Fig.* 230) mounted upon an insulated staff and covered with moistened cotton. This is placed against the enlarged tube and attached to the positive pole of the direct current battery, a current flow of thirty or more milliamperes being maintained for about ten minutes every other day. Under these circumstances the discharge from the uterus becomes

greenish, showing that there is a transfer of copper ions into the tube itself. The phoresic action of the copper salts is thus demonstrated. Under these conditions the discharge will cease after a succession of treatments.

Where, however, there is an associated metritis, intra-uterine applications may be tentatively made according to the method described under that head, with marked benefit to the salpingitis.

Where pus is encysted or of gonorrheal origin the rule is to abstain from intra-uterine applications, though cases are recorded in which cures have undoubtedly been effected in such instances by the combined vaginal and intra-uterine treatment.

Pelvic Peritonitis.—*Direct current.* This manifests itself by a certain rigidity and fixation of the vault of the vagina. This disappears readily under positive vaginal applications of the direct current, assisted by applications of the induced current.

The *static wave current* is also useful in this condition, a flexible metal electrode being applied to the hypogastrium.

Menorrhagia.—*Direct current.* Remembering that the positive pole tends to check hemorrhage, we introduce a ball electrode (*Fig.* 230) well covered with moistened cotton into the posterior vault of the vagina, and attach it to the positive pole. A current strength of from thirty to forty milliamperes may be employed for ten minutes, three times a week for three weeks preceding the menstrual flow. Here rapid results may be obtained by introducing a suitable electrode

covered with moistened cotton into the uterus, and still more rapid by cupric-phoresis, which is ordinarily not necessary.

Erosions of the Os.— *Cupric Phoresis.* These result usually from acrid discharges due to endometritis or salpingitis. When these are corrected erosions of the os usually disappear. Should they continue they are readily cured by cupric-phoresis. For this purpose a cup-shaped electrode (*Fig.* 234) conforming to the shape of the cervix and composed of copper may be used for cupric-phoresis, employing the technique already explained. The treatment lasting a few

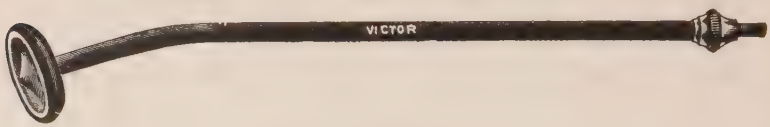


Fig. 234.

minutes and employing a current strength of from ten to twenty milliamperes will speedily effect a cure.

Ovaritis.— *Cupric Phoresis.* This is of course very frequently associated with salpingitis, metritis, and endometritis. The treatment suitable in this condition is the employment of the ball electrode (*Fig.* 230), covered with moistened cotton and attached to the positive pole of the constant current battery. The current may have a strength of from thirty to fifty milliamperes, and each treatment may continue for ten minutes, being given three times each week.

Induced current. This treatment may be succeeded by an induced current from the secondary coil, with rapid vibrations, when there is much pain.

Ovarian Congestion.— *Direct current.* For this condition it is sufficient to send a direct current through the pelvic organs by means of pads placed over the hypogastrium and under the lumbar-sacral region. The current strength should be from thirty to fifty milliamperes. With this treatment, as with the others already described, whatever associated treatment the case demands should be carefully prescribed.

Static wave current. An electrode of soft metal may be placed over the seat of congestion and treatment continued for twenty minutes. The rods may be separated from one to six inches. In all cases of pelvic trouble, where congestion which is not of an infective nature exists, the static wave current, because of its control over non-infective congestions, is a highly useful method of treatment.

Fibroids.— *Direct current.* A renewed interest has of recent years manifested itself in the treatment of fibroids by the use of the direct current. The method introduced by Dr. Apostoli has undergone certain modifications. In a series of eighty-six cases reported by Dr. Massey, there was a percentage of 85.33 per cent of successes. In a series of one hundred and four cases reported by Drs. Thomas and Skene Keith, the practical successes were fully 75 per cent, with a much larger percentage if twenty-one cases are included in which partial success was attained.

The method employed in the treatment of these cases is that already described in the treatment of

inflammatory conditions of the uterus. The positive pole is employed because of its hemostatic, analgesic, and hardening effect. For this purpose a uterine sound made of platinum is bent at the proper angle and coated with shellac by heating the sound and fusing the scales around the shank up to the required distance from the distal end. This affords perfect insulation, and leaves uncovered only that portion which is to be brought in contact with the interior of the uterus. Some fibers of cotton are now wound around the distal end of the sound, and soaked in a solution of adrenalin chloride. The sound is then introduced, a large abdominal pad being attached to the negative cord. Current strengths up to two hundred and fifty milliamperes may be employed. The treatment should be given once or twice weekly and may continue for ten minutes.

Cupric Phoresis. In some instances it is desirable to employ metallic phoresis, in which case a copper sound upon an insulated staff may be used. The results from metallic phoresis are likely to be much more rapid than from the simple direct currents.

Equally good results may be secured by placing a copper ball carefully covered with cotton or other material in the posterior vault of the vagina against the fibroid mass.

Carcinoma Uteri.— For the treatment of this disease by the anodal diffusion of zinc-mercury ions, the reader may consult Dr. Massey's " Conservative Gynecology."

Menopause.— *Direct current.* An intra-uterine sound (*Fig.* 230) attached to the negative pole is intro-

duced into the uterus, the indifferent pole being placed upon the abdomen. A current of from fifteen to twenty milliamperes is allowed to pass for ten or fifteen minutes. The determination of blood toward the uterus by this procedure gives relief to the distressing symptoms of the menopause.

Induced current. A bipolar intra-uterine sound is introduced into the uterus and attached to the poles of an induction coil.

Stimulation of the Thyroid Gland. Moistened pads attached to the poles of a constant current battery may be placed upon each side of the thyroid gland. Small currents are sufficient to reduce the sense of cerebral fulness characterizing this condition.

Fig. 235.

Static Insulation. Twenty minutes' application may be given for the purpose of equalizing circulation and relieving cerebral congestion.

Subinvolution of the Uterus.— *Induced current.* A bipolar uterine electrode (*Fig.* 235) should be introduced into the uterus and attached to an induction coil having five hundred interruptions per minute.

Direct Current. An alternative treatment is furnished by the direct current. An intra-uterine electrode is carried into the uterus and attached to the positive pole of the direct current battery. The

negative pole is attached to a moistened pad on the abdomen. The current strength may be twenty-five milliamperes and the treatment should be given every other day and last for ten minutes.

CHAPTER II

DISEASES OF THE GENITO-URINARY ORGANS

Urethral Strictures. The method of curing urethral strictures, as carefully elaborated by Dr. Robert Newman, of New York City, is vastly superior to the older method of dilatation, and when properly applied obviates the necessity of resorting to cutting operations. As already taught, the negative pole softens scar tissue and, when applied to fibrous constrictions, quickly absorbs and dissolves them. The principal points to be noted in this electrolytic treatment of urethral strictures are: (1) The use of the negative pole. (2) Small currents, not usually exceeding five milliamperes. (3) Intervals of a week between treatments.

The advantages to be secured are: (1) Immediate relief. (2) Applicability to every variety of stricture. (3) Freedom from pain. (4) Absence of hemorrhage. (5) Freedom from danger. (6) Permission of patient to pursue his usual vocation. (7) Permanence of cure without relapses.

Technique. The patient may take any position that is comfortable, the recumbent position being preferable. A *bougie à boule* is first passed to ascer-

tain location, character, and size of stricture, of which a careful note is made. When these points have been ascertained, an electrode is selected which is about three sizes larger than the size of the stricture to be treated. It is well lubricated and introduced into the

Fig. 236.

urethra and passed up to the stricture and allowed to rest against it. The indifferent pole is attached to a pad electrode, which may be placed upon the abdomen or thigh. The current is now turned on, not exceeding five milliamperes in strength. The process of absorption begins at once and the electrode passes along the urethra until the next stricture or strictures are reached, if there happen to be more than one. The electrode is then withdrawn slowly, the current being gradually turned off before the removal of the electrode.

Where the operator is obliged to use batteries, a twenty-cell battery with zinc and carbon elements will be found to serve his needs. A milliamperemeter together with rheostat ought of course to be employed.

The failure to secure perfectly satisfactory results will be found to depend upon neglect of some one or more of the points enumerated in the above description of the electrolytic absorption of urethral strictures. Figure 236 represents a set of olives which are mounted as required upon an insulated staff pro-

vided with a socket for the reception of the connecting cord.

Chronic Urethral Catarrh or Gleet. Where this is not dependent upon stricture it may be effectually cured in the following manner. By means of a cannula a long straight probe, wrapped with absorbent cotton and soaked in a two per cent solution of sulphate of zinc, is introduced into the urethra. The cannula is then withdrawn, and the probe attached by a conducting cord to the positive pole of a constant current battery, and allowed to remain for about ten minutes. The current should not exceed two milliamperes.

Gonorrhea. Dr. Caré, of Cherbourg, has reported remarkable results in the treatment of both acute and chronic gonorrhea by the use of a sound made of fine silver wire, wrapped with thread, dipped in gelatine and finally soaked in a one per cent solution of silver nitrate. This is connected with the positive pole of a direct current battery with an initial strength of one milliampere, increased finally to ten milliamperes. The indifferent electrode is placed upon the abdomen. The current is permitted to flow for one hour or less. The gonococci disappear entirely after the first treatment, the urethritis being at once converted from a specific to a simple inflammation. Upon examination with the urethroscope the urethra is found to be white and glistening. The discharge ceases frequently after a single treatment.

An alternative method is to employ a perforated

hollow rubber electrode made to receive a copper probe. The probe is covered with absorbent cotton saturated with normal salt solution. A current strength of from five to eight milliamperes may be continued for ten minutes and repeated every fourth day. Figure 237 illustrates this electrode, which for this purpose must have perforations extending its full length.

A much better treatment than this for chronic urethritis consists in the employment of silver sounds ranging from twenty-one to twenty-five of the French scale, according to the calibre of the urethra. This

Fig. 237.

should first be determined by the use of the *bougie à boule*. The sound should be provided with a socket for the reception of the cord tip. A current strength of from eight to ten milliamperes may be employed for ten minutes. The treatment may be given at intervals ranging from three days to a week. Cures in the most obstinate cases of chronic urethritis may be made frequently in three or four treatments. The usual aseptic precautions are to be observed and a weak solution of cocaine employed if desired.

Prostatic Hypertrophy. For the relief of this distressing disorder several methods have been devised. These include the electro-cautery and electrolysis, besides other methods hereafter described.

Bottini's method of destroying the prostate by means of massive currents has been largely abandoned in favor of prostatectomy. Much to be preferred to this is Newman's method of reducing the size of the prostate by flashes in an electro-cautery sound. The specially devised sound having been introduced into the urethra and connected with the constant current battery, the current is allowed to pass for a moment and immediately cut off. Several flashes may be given in different places if deemed necessary. The operation is not usually painful. The originator of

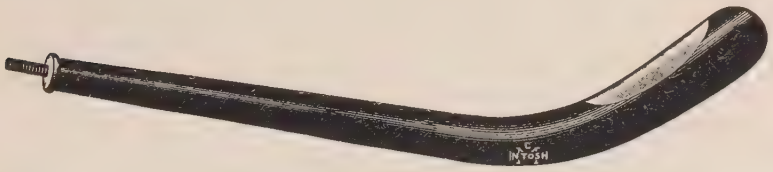


Fig. 238.

this method of treatment says: "It has benefited or cured all cases under observation."

The method of electrolysis includes the use of weak and strong currents. With weak currents a flat metal electrode is applied to the prostate per rectum and attached to the negative pole. A current of from five to fifteen milliamperes may be employed. Dr. Bowen's prostatic electrode (*Fig.* 238) may be used for this purpose.

Dr. Massey employs strong currents either by rectum or urethra. The current is permitted to run as high as seventy milliamperes and is gradually in-

creased and diminished. He calls this the " swelling method." Each constant current treatment is succeeded by primary induction coil treatment.

The method of Dr. Neiswanger deserves mention. This consists in the use of a specially devised electrode (*Fig.* 237) which consists of a hard rubber tube having the proper urethral curve. The tube is closed at its distal end and perforated for a distance of two inches from the distal end. Within the tube is a twisted copper applicator with a socket at the proximal end for the reception of a cord tip. Cotton is twisted around the distal end of the applicator and soaked in a solution of iodide of potassium (grs. xx to aqua ℥1). The electrode being introduced and carried its full length is connected with the negative electrode of a constant current battery, the positive being a well-moistened electrode placed upon the abdomen. A current flow of ten milliamperes is attained and continued for ten minutes. The effect is to liquefy and soften the enlarged gland and deposit iodine in the tissues.

In order to strengthen the detrusor muscle whose office is partly to raise the floor of the bladder to a level with the urethral orifice, a slowly interrupted induced current is now carried into the bladder before removing the electrode. The effect is to massage the muscle and stimulate the action of the absorbents.

Where the urethra is hypersensitive, following gonorrheal infection or prostatitis, the same electrode may be used with the exception that the rubber tube

is perforated its entire length. Cotton is then wrapped around the applicator and soaked in a normal salt solution. The electrode is attached to the positive pole and the treatment continued for ten minutes with a current strength of ten milliamperes. The treatment may be given every four or five days.

X-ray. Very favorable results are reported from the use of the X-ray. Caracelli and Lucaselli report ten cases which were much benefited by this treatment. The scrotum, penis, and thighs were protected by lead and the perineum exposed to the rays. Moskovitz reports three cases with good results. One was entirely cured. According to his method a rectal speculum was employed, the surrounding parts being protected by lead.

Orchitis and Epididymitis.— *Direct Current.* Here several observers have reported excellent results. The positive pole of the direct current battery is attached to a well-moistened pad and applied to the affected parts, the kathode being placed on the abdominal wall. A current of one half of one milliampere may be passed for three minutes, being increased from day to day until three milliamperes are reached. It is said that rest may be dispensed with and pain quickly and effectually relieved.

Phoresis. Dr. Duboc of Rouen has reported two chronic cases of orchitis and epididymitis which were promptly cured by anodal phoresis of a twenty per cent solution of iodide of potassium. Pads were placed on opposite sides of the affected testicle and a current strength of twenty milliamperes continued for twenty minutes.

INCONTINENCE OF URINE.— Three types may be noted. In the first class there is weakness of the sphincter of the bladder, urine escaping during muscular effort on sudden action of the abdominal muscles, as during coughing. In the second class there is bladder irritability, manifesting itself especially in women, accompanied by pain and spasm and frequent micturition. In the third class there is nocturnal enuresis, particularly in children.

Where there is weakness of the vesical sphincter, measures should be taken to strengthen it. This may be accomplished in various ways. A urethral sound is introduced into the female urethra and a very rapidly interrupted induced current is broken up into comparatively long periods by the rheotome for the purpose of massaging the vesical sphincter. This may continue at first for three or four minutes. The indifferent pole should be placed over the lumbar region. Treatments may be given at intervals of three or four days.

Where an incontinence of this variety manifests itself in boys, it is better to produce this massage of the vesical sphincter through the rectum, placing the electrode against the prostatic urethra and the indifferent pad upon the perineum or above the pubes.

An alternative treatment in the case of women is to place a short electrode in the rectum and the indifferent pad above the pubes, using an induced current as above described.

In the second class of cases where incontinence, occurring mostly in women, is due to alteration of the

character of the urine with irritability of the bladder mucosa, there is little benefit to be obtained from electric treatment.

Nocturnal Enuresis. Various explanations for this condition are furnished. Ultzman assumes that there is a disproportion between the innervation of the detrusor and sphincter muscles, the latter being defective. The treatment would, therefore, demand stimulation of the sphincter.

Another explanation which no doubt possesses a measure of truth assumes that nocturnal enuresis is simply a persistence of the infantile mechanism of micturition, and that the automatic action of the bladder continues through failure to educate the inhibitory centers. According to this view it is necessary to stimulate the cerebral centers by producing painful local impressions which bring the inhibitory centers into close relation with the reflex centers in the spinal cord.

Upon the assumption that the vesical sphincter is weak we must find some method by which it may be strengthened. It is a matter of observation that operations upon the rectum frequently result in temporary retention of urine through stimulation of the vesical sphincter. This results from the fact that the anterior hemorrhoidal nerves arising from the pudic branch of the sacral plexus supply the lower part of the bladder and sphincter vesicæ as well as the sphincter ani externus and internus and the vagina. Adopting this hint we proceed to stimulate the rectum. In small children a well-oiled rod about the size of a

lead pencil and two inches long mounted upon an insulated handle is introduced into the rectum, the other pole being a well-moistened pad placed upon the perineum. The induced current is employed with slow interruption. In small children the current should at first be very weak, but may be gradually increased in strength. The treatment should be given daily, then every other day, and should continue for ten or fifteen minutes. In larger children and adults a larger electrode may be employed.

Assuming on the other hand that nocturnal enuresis is a persistence of the automatic mechanism of micturition, we should place great stress upon the educative procedures and psychotherapeutic methods which are necessary to evoke the control of the centers of inhibition in the cerebro-spinal system. With this is to be associated the use of induced currents applied to the lumbar centers and perineum, carrying the treatment to the point of exciting a certain degree of pain. The direct current may also be used with slow interruption for the same purpose. The suggestive and electric treatment are to be carried on simultaneously, control being evoked by the association of the cerebral and reflex spinal centers.

Varicocele.—*Direct Current.* Recalling that the positive pole acts as a vaso-constrictor we may employ a specially devised electrode and apply it to the scrotum for the purpose of narrowing the lumen of the tortuous veins constituting the pampiniform plexus. Figure 11 represents an electrode designed by Neiswanger. The portion of the scrotum containing the

enlarged veins is placed between the plates, which are carefully covered on their inner surface with moistened cotton, the indifferent pad being placed upon the abdomen or lumbar region. The treatment lasting for ten minutes, and employing a current strength of ten milliamperes, is given daily so long as the skin of the

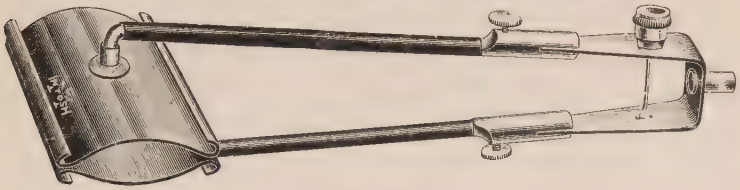


Fig. 239.

scrotum will permit. In order to facilitate and hasten the treatment the cotton may be moistened with the tincture of thuja.

Spermatorrhea.— *Direct Current.* The positive pole should be attached to a rectal electrode (*Fig.* 230) neatly covered with chamois skin and soaked in a mixture of ten per cent ichthyol in glycerine. The negative pole is attached to a moistened pad placed upon the abdomen. The treatments should be given daily and last for ten to fifteen minutes. The relaxed seminal vesicles and ejaculatory ducts feel the antiphlogistic and contracting effect of the positive pole and tend to recover their normal tone.

CHAPTER III

DISEASES OF THE RECTUM

Hemorrhoids.— According to their location these are of two kinds, external and internal. The former are thrombotic or cutaneous, the latter capillary or venous.

Thrombotic hemorrhoids are so quickly and satisfactorily cured by the knife that it seems unnecessary to devise a treatment by electricity. They may be opened like an abscess and the clot turned out. When there is much redundancy of tissue, fine sutures of silk may be carried through the base of the tumor, and after incision the edges may be trimmed down and drawn together. In order to render this procedure painless, a drop of pure carbolic acid may be placed upon the cutaneous margin, a hypodermic needle introduced at this point and a ten per cent solution of cocaine slowly and gradually injected.

Electro-Cautery. Instead of the knife the electro-cautery brought to a dull red heat may be employed.

Cutaneous Hemorrhoids, or tags, may be removed by the knife after anesthetizing, or they may be removed by electro puncture, one or more rounded or flat needles attached to the negative pole

being introduced near their union with the body and successively carried through until a linear area of tissue destruction is produced. The nutritive connection being destroyed the tag soon drops off. (*Fig.* 240.)

Capillary Hemorrhoids. These do not project into the lumen of the bowel to any considerable distance. They are therefore difficult to locate. They are of the nature of a nævus or telangiectasis. They are characterized by a marked tendency to hemorrhage, patients suffering frequently from anemia without being aware of the cause of their diminished strength. These are readily cured by the application

Fig. 240

of the electro-cautery. This converts the capillary network into an eschar, and quickly effects a cure. For this purpose it may be necessary to employ a rectal speculum with a slide which upon withdrawal reveals the location of the diseased area.

Arc Light. Cleaves (*Advanced Therapeutics, January,* 1908) reports great improvement in a case of hemorrhoids, attended with profuse hemorrhage, from the application of the marine searchlight twenty-five amperes, to abdominal, precordial, spinal, and particularly lumbar-sacral areas. Within two weeks the hemorrhage was controlled.

Venous Hemorrhoids. It is rarely necessary to treat these tumors unless they prolapse. Where they

do not prolapse they are usually not painful. In this case they can be recognized by means of a slide speculum, and thus treated. Where they are sufficiently swollen they can be made to prolapse by straining, as in defecation. They are thus brought to view, and are easily treated by electrolysis. They may be anesthetized as above described by a four per cent solution of cocaine. When properly prepared one or more round sewing needles mounted upon a handle are attached to the negative pole of a direct current battery, the positive pole being connected with a large pad upon the abdomen. The needles being introduced into the tumor, its surface becomes white, and minute hydrogen bubbles soon make their appearance. The needles are then withdrawn, and if necessary reintroduced. The tumors shrivel up in a few days and disappear painlessly. This is undoubtedly an efficacious and satisfactory method and does not require the patient to absent himself from his work.

When divulsion is desired, as where the hemorrhoids do not present themselves sufficiently for ready treatment without the use of a speculum, the parts may be rendered anesthetic by means of phoresis. A conical-shaped copper electrode is covered with cotton (*Fig.* 241), moistened by a four per cent cocaine solution, attached to the positive pole of the direct current battery, and pushed into the rectum. The negative electrode is a large pad placed upon the abdomen. A current of thirty milliamperes may be passed for about ten minutes. A certain amount of divulsion may thus be painlessly accomplished, and a

very much more complete anesthesia obtained than by hypodermic injection.

There are certain alternative methods which may be employed, which, however, are inferior to those already described.

Fig. 241.

Metallic Phoresis. For the treatment of venous hemorrhoids a copper electrode (*Fig.* 241) is carefully covered with chamois skin and moistened with a ten per cent solution of ichthyol in glycerine. This is attached to the positive pole of the direct current battery, and a current of from ten to fifteen milliamperes is allowed to flow for ten minutes. The negative pole is a large pad placed upon the abdomen. The treatment is repeated every second day. Here the astringent effect of the positive pole manifests itself in a rapid reduction of the size of the tumors.

Electro-Cautery. The prolapsed tumors may be quickly touched with the dull red blade of the electro-cautery. They are then anointed with vaseline or other lubricant, and carefully returned to the bowel. A succession of such treatments at intervals of a week will cause the disappearance of these tumors.

High Frequency. Where the congestion has not resulted in an alteration of the tissues, and is therefore comparatively recent, a glass vacuum tube (*Fig.* 242), carrying a high frequency current, introduced into the rectum, is capable of restoring muscular tone

to the weakened rectal walls and dissipating the hemorrhoidal swellings.

Bokenham reports very favorable results in a large number of cases treated by high frequency currents.

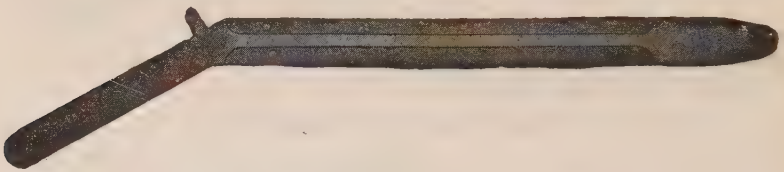


Fig. 242.

Fistula.— *Metallic Phoresis.* This painful disease readily lends itself to electrical treatment. For this purpose a long copper probe is introduced into the fistula (*Fig.* 242) and attached to the positive pole of the direct current battery, a large pad being attached to the negative pole and placed upon the abdomen. A current of from five to twenty-five milliamperes may be passed, depending upon the size of the channel, and may be continued from five to ten minutes. The antiseptic copper salt is deposited in the tissues, the pyogenic membrane destroyed, and the healing process started. To the

Fig. 243.

objection that branches are not thus reached, it is answered that the deposit of cupric salts is not limited to the fistula through which the electrode passes, but where the current is sufficiently strong involves contiguous territory. In this respect also it is superior

to the surgical treatment of this painful disease, since if an associated tract is not discovered the cure may nevertheless be effected. Three or four days should elapse between treatments, and a smaller wire used at each visit. Local anesthesia should be employed, and where this is sufficiently profound, larger currents may be employed and the fistulous tract cured by one treatment.

Rectal Stricture.— The same method applied so successfully to the cure of urethral stricture may be employed here. For this purpose sets of electrodes of copper, brass, silver, or nickel plate are provided, of different sizes, in length from one fourth inch to one and one fourth inches, and having a circumference from one and one eighth to three inches. These are mounted upon an insulated staff which may be flexible or stiff. Beginning with the smallest size which resists passage, the electrode is connected with the negative pole, and a current of from five to twenty milliamperes is employed. The weakest current capable of performing the work should be employed. The treatment may last from five to fifteen minutes. For other details the student may consult the paragraph on urethral stricture, the technique in the two operations being similar.

Prolapse of the Rectum.— For the management of this condition, especially where it is complete, resort must frequently be made to surgery. Where it is partial, the bowel must first be replaced and measures employed to hold it in position. If these are not successful, the mucous membrane may be

anesthetized by four per cent cocaine, and the dull red cautery passed longitudinally over the protruded bowel, making four linear applications at equidistant points. The effect is to bind the mucous membrane to the underlying tissues.

Cupric Phoresis. Frequently the use of the copper electrode (*Fig.* 241), according to the technique described under the treatment of hemorrhoids, will accomplish the same results.

High Frequency.— In recent cases the high frequency vacuum electrode may be successfully employed. (*Fig.* 242.)

Pruritus Ani. *X-ray.*— This frequently has its origin in an ulcer or fissure, which discharges an irritating secretion upon the tissues around the anus. These become rough and thickened, and the seat of intolerable itching. The obvious preliminary treatment is to cure any condition, like ulcer, fissure, hemorrhoids, prolapse, stricture, or prostatitis, which may give rise to the irritating discharge. When this has been corrected the X-ray is to be employed, the results of which have been highly successful here, as they are elsewhere in pruritic conditions. A soft tube should be selected, and treatments lasting ten minutes three times a week should be given, after the operator has tested the tolerance of the tissues to X-ray exposure.

Radium should be employed if the case continues refractory. This treatment secures rapid and brilliant results.

High frequency vacuum discharges are useful,

more particularly in cases where the tissues have not undergone thickening.

The static brush discharge produces a somewhat similar result.

Fissure or Ulcer.—This painful disorder is readily cured by the application of the dull red cautery. A few drops of a four per cent solution of cocaine must first be injected, or brushed over the surface. Where there is much spasm of the sphincter, the cautery may be heated to a white heat, and the edge of the knife carried a slight distance into the tissues. The results are highly satisfactory. The bowels should be confined for a few days, after which a laxative, like castor oil, should be given. The patient should be kept in bed for several days, and the wound surgically dressed. If, however, the fissure has demanded only a superficial application of the cautery, the patient will not need to stay away from business.

Whenever an ulcer is accessible in the rectum it may be similarly treated. Suitable medicinal and hygienic treatment should be associated with the use of the cautery whenever demanded.

High Frequency Vacuum Electrode. These are sometimes useful, and may be employed when the cautery is objected to. Undoubtedly the dilatation secured by the introduction of the tube assists in the cure (*Fig.* 242).

Non-Malignant Growths of the Rectum. *Hot wire snare.*—These are usually called polypi, but they may include any of the following varieties:

adenomata, fibromata, papillomata, teratomata, lipomata, cystomata, enchondromata, and angiomata. They may be removed by the use of the hot wire snare, heated to a dull red heat. Hemorrhage is thus avoided and the stump of the wound seared.

CHAPTER IV

DISEASES OF THE NOSE AND THROAT

Acute Rhinitis.— *Electro-Cautery.* The treatment here is preventive rather than curative. Where there is considerable swelling of the erectile tissues of the nose following several attacks of rhinitis, producing hyperesthesia of the mucous membrane and increased susceptibility to fresh attack, a few applications of the flat side of a cautery knife at a red heat over the mucous membrane lining the inferior turbinated bones is attended with marked benefit. This should be done alternately in each nostril at intervals of three or four days, after using a four per cent solution of cocaine. The treatment should, of course, be preceded by an alkaline spray, and be done under thorough illumination. The home treatment should consist of cleansing alkaline washes administered twice daily, followed by the application of camphorated oil to the cauterized areas.

Electrolysis. In both the acute and chronic conditions of intumescent rhinitis, electrolysis may be employed instead of the electro-cautery. A current of one to three milliamperes is carried into the tissues by means of a platinum needle attached to the

positive pole and continued for from two to eight minutes. Four per cent solution of cocaine should first be employed.

Direct Current. In the chronic intumescent condition the direct current may be employed, the positive pole being placed in the nose and the indifferent pole upon the shoulder. This method is slow and unsatisfactory.

Chronic Rhinitis.— By this is meant a permanent tumefaction of the erectile tissue of the nasal cavities with histologic change. The tissues are resilient under the presence of a probe. Here the treatment described above is applicable.

High Frequency Vacuum Electrodes. In both acute and chronic rhinitis a specially constructed vacuum tube carried into the nares has been found useful in some cases. The current may also be applied over the maxillary sinuses by means of an ordinary body electrode.

The Concentrated Arc Light. The eyes being properly protected the concentrated rays of the arc lamp are thrown upon the face with great relief in cases which have not become very chronic.

Incandescent Bath Cabinet. Similarly for relief of acute conditions, exposure of the nude body to the radiant light bath is of very great benefit, and in many cases will promptly abort a " cold," or relieve congestion of the nasal passages even when well established.

Hypertrophic Rhinitis.— *Electro - Cautery.* Here long-continued inflammation has resulted in

an interstitial production of fibrous tissue. The probe will not imbed itself in this tissue, and cocaine will not markedly reduce the hypertrophy. The simple application of the cautery knife will produce but little effect in this condition. Where, however, the neoplastic tissues are not large, the use of the cautery knife may be preceded by linear incisions across the hypertrophic areas. The cautery knife is then introduced into the wound at a red heat and the tissue bound down to the underlying structures.

Where the neoplastic tissues are large the cold wire snare or the cautery loop may be used. If the latter is used the growth may first be transfixed by a needle and the loop carried over this and brought to a red heat. It must not be forgotten that these cases are to be carefully kept under observation in order to prevent adhesions and to promote satisfactory healing.

Hyperesthetic Rhinitis, or Hay Fever.—*Electro-Cautery.* Here hyperesthetic areas are to be sought for and cauterized by the application of the cautery at a white heat. This is to be done systematically, about four spots being cauterized at a sitting. The cauterant effects are designed to be superficial and comparatively painless. The cautery is so rapid in its action that the nerve filaments are destroyed before they have time to convey sensations.

Electrolysis. The electrolytic needle may be employed instead of the electro-cautery in touching the hypersensitive spots in the nasal passages.

Blue Light. The soothing influence of the arc

lamp screened by blue glass should always be tried in these rebellious cases.

Simple Atrophic Rhinitis.— *Direct Current.* The constant current should be employed as described under chronic intumescent rhinitis, together with vibratory massage over the whole mucous membranes of the nose.

Fetid Atrophic Rhinitis–Ozena.— *Cupric Phoresis.* Here unquestionably the best method of treatment is cupric phoresis. The crusts having been thoroughly removed, and the areas anesthetized by a four per cent solution of cocaine, a copper electrode is attached to the positive pole and introduced into the tissues of the middle turbinate. The oxychloride of copper is carried into the diseased tissues, effectually correcting fetor, and tending to restore the tissues to a normal condition. A current of from five to fifteen milliamperes may be employed. The other nostril is similarly treated, the copper needle being exchanged for a new one from time to time.

Recurrent Nasal Hemorrhage.— This is readily treated by the application of the electric cautery brought to a red heat to the diseased area. In obstinate cases cupric phoresis should be employed, a copper electrode attached to the positive pole being used to touch the surface of the ulcer, the indifferent electrode being placed upon the shoulder.

Adenoids.— In the judgment of the author electricity is not adapted to the removal of these growths in children. In older people, where the

naso-pharynx can be thoroughly illuminated, and the velum palati is supported with a retractor, they may be removed by the electro-cautery or post nasal cautery knife.

Acute Pharyngitis.— The same treatment may be employed as in laryngitis. (See page 375.)

Follicular Pharyngitis, or Clergyman's Sore Throat.— A platinum loop twisted into the form of a small corkscrew is heated to a red heat and passed into the inflamed follicle. Not more than four follicles should be treated at a sitting. After an interval of three or four days the treatment may be resumed. The results are highly satisfactory.

(*a*) Simple Tonsillitis.— *Blue Light.* This treatment will at times exercise a very remarkable control over acute inflammations of the throat and tonsils. The blue light should be thrown upon the anterior and lateral aspects of the neck over the throat and larynx. The exposure may continue from fifteen minutes to half an hour, and should be made every three hours if needed. For this purpose a small hand lamp with a proper screen may be attached to an electric lamp socket.

(*b*) Follicular Tonsillitis.— *Electro-Cautery.* Here one or more crypts are frequently filled with a cheesy material which imparts an offensive odor to the breath. These are first thoroughly cleansed, and then treated with the cautery knife, which is permitted to remain in each diseased crypt about a second. Three or four crypts may be treated at a sitting.

(*c*) Hypertrophic Tonsillitis.—*Electro-Cautery.* Where children require operation it is better to resort to general anesthesia and surgery. In older patients afflicted with the same trouble the electro-cautery loop or ignipuncture may be used successfully. The technique is similar to that described in treating nasal tumors (*p.* 373). Where ignipuncture is employed the electro-cautery knife is introduced into the parenchyma of the tonsil. Five or six punctures in each tonsil may be given at each sitting, with an interval of three or four days between treatments. A four per cent solution of cocaine should be employed for local anesthesia.

(*d*) Phlegmonous Tonsillitis or "Quinsy Sore Throat."—*Light Treatment.* This very painful and harassing affection, due to the formation of abscesses in the tissues around the tonsil, with secondary involvement of the tonsil itself, is more accurately called "peritonsillar abscess." Great relief is obtained from prolonged applications of light and heat from a concentrated incandescent lamp. Where the abscess is not aborted, there is great relief of pain with a much more rapid development of pus and a shortening of the period of suffering.

Necrosing Ethmoiditis.—*Zinc Phoresis.* A zinc electrode of suitable shape and size should be introduced into the nose against the necrosed area, the indifferent pole being placed upon the shoulder or nucha. A current strength of from five to ten milliamperes or more should be employed for five to ten minutes. Two or three sittings should be sufficient.

Neoplasms of the Nose.— *Electro-Cautery.* These are readily removed by the electro-cautery snare, which is specially useful where there is a tendency to hemorrhage, or where the growths are sessile.

Zinc Phoresis. Malignant tumors of the nose, pharnyx, and larynx which are inoperable, or in which operation has been declined, are best treated by zinc phoresis. A zinc electrode is connected with the positive pole and applied to the diseased area. A large dispersing electrode is placed upon the back or shoulder, and from ten to thirty milliamperes carried into the tissues. The treatments are continued at intervals according to the indications.

Diseases of the Accessory Sinuses.— *Cupric Phoresis.* Where these have been opened and drained and there is a persisting discharge, cupric phoresis should be employed to sterilize the cavities and promote healing. One application may be sufficient for this purpose, and may shorten an otherwise long and tedious recovery. After anesthetization a suitable electrode should be introduced into the cavity, and a current of from one to five or ten milliamperes, or more, employed according to the size of the indifferent pad and the tolerance of the patient.

Hypertrophy of the Lingual Tonsil.— *Electro-Cautery.* The electro-cautery is well adapted for the relief of this condition as well as glandular enlargements at the base of the tongue.

Pharyngomycosis.—*Electro-Cautery.* This con-

dition is due to a fungus in the pharynx, often the leptothrix. It frequently, however, involves the faucial tonsils and the base of the tongue. Each infected focus should be destroyed by the electro-cautery. If recurrence takes place cupric phoresis should be employed. This rarely fails to afford complete relief.

Leukoplakia.— *X-ray.* This is a whitish-purple elevation, usually upon the dorsum or edges of the tongue or buccal mucous membrane of the cheek. It is accompanied with cracks and fissures of the surrounding tissues. It is dangerous because of its tendency to degenerate into a malignant growth. It is possible that it is already epitheliomatous in character. It is rebellious to treatment. For this condition the X-ray should be employed. For this purpose a low tube with protecting cover and tubular attachment should be used. The end of the tube should be held against the diseased area, completely encircling it. The treatment should be brief at first and increase in length as the tolerance of the patient is ascertained. The treatment should then be given twice a week and continue for ten minutes.

Electro-Cautery. As an alternative treatment the electro-cautery may be employed.

Elongation of the Uvula.— *Electro-Cautery.* This may be readily removed by the electro-cautery snare, the point of the uvula being held by a dressing forceps to secure accuracy of manipulation.

Hysterical Aphonia.— *Induced Current.* This may be treated by means of the induced current, one

electrode being applied on either side of the larynx, the patient meanwhile being directed to count from one to ten.

High Frequency Vacuum Electrode. Instead of the induced current the mono-polar high frequency vacuum electrode may be employed.

Laryngitis.— *Concentrated Arc Light.* The concentrated light from an arc lamp should be thrown upon the larynx in both the acute and chronic conditions.

Blue Light. Where there are much pain and discomfort the blue light should be substituted.

Tubercular Laryngitis.— *Cupric Phoresis.* An admirable treatment, demanding no great technical skill for its administration, is cupric phoresis. A small, chemically pure bulb of copper mounted upon a covered insulated staff is attached to the positive pole of the direct current battery and under full illumination from the laryngeal mirror is brought into contact with the diseased area. The larynx should be anesthetized with a ten per cent solution of cocaine. The treatment should last five minutes and should be repeated every other day. The current strength should range from one to three milliamperes. The indifferent pad should be placed upon the neck.

X-ray. This should be faithfully applied as an alternative treatment in this grave affection, the superficial location of the disease being favorable for this method of treatment.

Electro-Cautery Punctures.— Less useful, but coming rapidly into favor with nose and throat

specialists, is the method of treatment by means of electro-cautery punctures.* Obviously by this method there is grave danger from destruction of normal tissue and the production of cicatrices, while by the method of cupric phoresis there is wide infiltration by the germ-destroying oxychloride of copper without damage to surrounding parts.

* Laryngeal Tuberculosis. Casselbury, *Journal of the American Medical Association*, Aug. 7, 1909.

CHAPTER V

DISEASES OF THE EYE AND ACCESSORY APPARATUS

Chalazion — Meibomian Cyst. — *Electrolysis.* The electrolytic needle attached to the negative pole of a constant current battery is introduced into the cyst through the opening of the distended sebaceous gland, if it can be found, otherwise into the thinnest part of the enclosing wall. A current of from one to five milliamperes may be employed for a minute or more if necessary. The fluid may escape from the cyst along the tract made by the needle with obliteration of the sac. Ten per cent solution of cocaine should be employed.

Trichiasis.— Here the electrolytic needle is indicated. Cocaine anesthesia should be as thorough as possible, as it is a somewhat difficult procedure to remove hair from the margin of the lids. The technique, however, does not differ from that described elsewhere for the removal of hair.

Herpes Zoster.— *Direct Current.* Where the nasal branch of the first division of the fifth nerve is afflicted with this disease, the cornea, iris, choroid, and other structures may be involved. Here the direct current has been successfully employed. A

current just strong enough to produce a sensation of warmth is necessary, the positive electrode being applied to the lid, the indifferent electrode to the nucha.

Trachoma.— *Cupric Phoresis.* For this painful and obstinate affection cupric phoresis affords an admirable treatment. The mucous membrane is thoroughly cocainized, and after eversion the granulated surface is touched here and there with the flattened surface of a small copper electrode attached to the positive pole of a direct current battery. The treatment is continued for ten minutes, with a current strength of about three milliamperes. The membrane quickly assumes the characteristic pale-green color due to the infiltration of the copper salt. The treatment may be repeated after a few days, if necessary.

Stricture of the Canaliculus and Nasal Duct.— The principles applicable to stricture elsewhere are utilized here. A small platinum probe or an ordinary lachrymal probe provided with a socket to receive a cord tip is introduced into the punctum and passed along the nasal duct. The electrode is then attached to the negative pole of the constant current battery and a current of from one to three milliamperes continued for about thirty seconds. The results thus secured are much more rapid than by the classical procedure of simple dilatation.

Opacities of the Cornea.— Alleman's method of treating this otherwise hopeless condition seems to have produced excellent results. His effort is to produce sufficient stimulation of the scar tissue to

bring about general absorption and the deposit of clear corneal tissue, without producing irritation and stasis. The cornea is anesthetized by cocaine. The operator stands behind the patient, whose head is thrown back in a reclining chair. With the thumb and forefinger of the left hand the lids are separated, and a small sponge electrode applied to the cornea, the positive electrode being applied by the patient to the cheek. The strength of the current is to be regulated by the tolerance of the patient, beginning with one half milliampere and increased to one milliampere if possible. The treatment may continue for four minutes and be repeated the following day.

Iritis.— *Direct Current.* Where there are adhesions and inflammatory deposits following an acute iritis, the mild, constant current has been found to possess much advantage. The negative pole applied to the closed lids with a current of from one to one and a half milliamperes, continued for a period of five minutes, should be employed. The treatment may be repeated at intervals of three or four days. Atropia, when not contraindicated, may be combined with the electrical treatment.

Scleritis.— *Direct Current.* In this obstinate disorder pain has been relieved by the application of the positive pole to the closed lids with a current of from one milliampere to one and a half milliamperes continued for three minutes.

Opacities of the Vitreous Humor.— *Direct Current.* While there has been diversity in the application of electricity to this serious disorder, the general

results have been favorable. Among the many methods employed is the following: Apply the negative electrode to the closed lids, the indifferent electrode being placed upon the nucha. Currents of from one to five milliamperes, continued for from two to six minutes and repeated every other day, may be employed.

Retinitis.— *Direct Current.* Where hemorrhage has taken place into the retina, absorption has been obtained by the application of the negative pole to the closed lid, with currents of from one to one and a half milliamperes, continued for five minutes and repeated two or three times a week.

In *Albuminuric Retinitis* the results of electrical treatment, as might readily be inferred, have not been encouraging, while in *Retinitis Pigmentosa* eminent ophthalmologists have reported a number of successes. The positive pole may be applied to the closed lid, the negative to the brow or temple. The current should not exceed one or one and a half milliamperes, and must be employed at intervals of four or five days for a long time.

Papillitis and Atrophy of the Optic Nerve. — Rockwell's experiments tend to show that direct and induced currents have a marked influence on the retinal circulation. In diseases so hopeless as these it would seem justifiable to employ any method which would give promise of the slightest improvement. The results in atrophy of the optic nerve have been most favorable where electrical treatment has been started early in the progress of the disease.

Erb's method consists in passing a current transversely through the temples in order to effect the optic nerve in the orbit, with reversals of the current, and then longitudinally from the nape to the closed lids. "Where neuritis predominates, the anode principally must be placed on the eye and the kathode only temporarily stabile; but when atrophy has come on the kathode chiefly on the eye after the anode has acted for a little stabile, and to a small degree labile."

Paralysis of the Ocular Muscles.— The results here are as good as they are in paralysis of muscles elsewhere. Erb's method consists in placing the negative electrode on the closed lid of the affected eye, and the positive electrode on the opposite side of the neck and occiput. Currents of one milliampere may be employed, lasting two or three minutes for each muscle, and may be repeated daily. Treatments may continue for a week, after which, if satisfactory results have not been obtained, the induced current may be employed.

Muscular Asthenopia.— Alleman has obtained excellent results from the use of the direct current applied to the closed lids for five minutes, with frequent reversals of the current.

Angiomata.— These vascular tumors, whether of the lid or orbit, may be removed by electrolysis. Platinum needles connected with both poles are passed into the growth and a current strength of from five to twenty-five milliamperes employed. The shaft of the needle should be insulated in order to protect the skin. General anesthesia is required.

Embedded Powder Grains.— These may be removed by the electro-cautery at a white heat. After removing those easily detached, the location of each grain is touched with the cautery long enough to cause a slough. Chloroform anesthesia may be required. The reaction is trifling, and after separation of the slough the resulting scar is almost imperceptible.

Ektropion.— This condition is readily corrected by everting the lid by means of a suitable retractor and carrying the point of an electro-cautery through the conjunctiva and cartilage at four equidistant points about one sixth of an inch from the margin of the lid. The cosmetic results are better than those obtained by plastic surgery. The treatment may be repeated where additional contraction of the tissues is needed, the electro-cautery being carried between the points of application in the previous operation.

Entropion.— Here the method is the same, except that the electro-cautery is applied to the skin instead of the mucous membrane.

Pterygium.— The following treatment is recommended by Dr. J. H. Davies, of Washington, Ohio. The growth is caught up by a rat tooth forceps, which is attached to the negative pole of a direct current battery. A current strength of from three to five milliamperes is permitted to flow until the vessels turn white. The same procedure is repeated in several places. At the expiration of a week or ten days, if any growth remains, the treatment is repeated.

Ophthalmia Neonatorum.—*Zinc Phoresis.* This method is employed by Ramsden (*British Medical Journal*). The positive electrode saturated with a two per cent solution of zinc sulphate is applied to the ocular and palpebral conjunctivæ. The negative electrode is held in the infant's hand by the nurse. Half a milliampere is permitted to flow for three minutes. In the case reported a cure was effected in two days after two applications.

Removal of Foreign Bodies.— These are oftenest pieces of iron or steel, which penetrate the chambers of the eye, producing greater or less damage to its refracting apparatus. They can frequently be renewed by the us eof magnets. (*Chap.* XI, *Part* I, *Fig.* 97.) To accomplish this result it is often necessary to enlarge the opening through which the foreign body entered.

CHAPTER VI

DISEASES OF THE LUNGS AND HEART

PULMONARY TUBERCULOSIS.— *Direct Current.* At the present time the attempt to cure pulmonary tuberculosis by the use of direct or induced currents seems largely to have been abandoned. Whether the experience of the future will serve to restore confidence in this form of treatment cannot at present be determined.

The X-ray. The physical treatment which seems to the author, both upon theoretical and practical grounds, to offer the best prospects of controlling this formidable disease is the conjunction of X-ray with light treatment. This is, of course, supplementary to appropriate outdoor and dietetic treatment, of which the importance is fully recognized.

The experiments of Dr. McCullough, of London, England, and Dr. Crane, of Michigan, tend to show that exposure to the X-ray increases the phagocytic power of the leucocytes, or in other words, increases the opsonic index. This is equivalent to the injection of autogenous vaccines, which raise the opsonic index and produce a series of positive tubercular phases. The dosage of the X-ray can be readily regulated by determination of the opsonic index.

Light Treatment. It has been shown in a previous chapter that while light does not kill bacilli in living tissue, it does, nevertheless, exert an inhibitory effect upon bacterial growth within the body through its influence upon nutrient media, and through the development of oxygen, which is fatal to the continued existence of anaërobic microbes. It follows, therefore, that exposure of the nude body to light must be highly beneficial to tuberculous patients, not only because of the inhibitory effect exerted upon the tubercle bacillus by light, but because of the improved metabolism which it inevitably produces. In order to effect this object the arc cabinet described in Chapter XXIII, Part I, is, in our northern climate, most effectual, inasmuch as it can be used throughout the year, and also because its output of chemical energy is very large. This treatment may be used most advantageously in connection with the X-ray treatment described above, to assist in the elimination of the toxins due to bacterial action.

Ozonized Nebulæ. In a previous chapter reference was made to the apparatus (*Fig.* 99) for the manufacture of ozonized nebulæ. These undoubtedly possess value, both for assisting expectoration and restraining cough.

Auto-Condensation. While in the judgment of the writer the treatment above described is best adapted to secure beneficial results in the management of these cases, Chisholm Williams has reported a very interesting series of cases greatly benefited by the use of the auto-condensation couch, of which an

interesting account is contained in his work entitled, "High Frequency Currents." His method is to give treatments lasting from five to twenty minutes every day, or at longer intervals, according to the circumstances of the case. The current strength ranges from one hundred and fifty to three hundred and fifty milliamperes.

Wave Current. Similarly the wave current may be employed for its tonic effect and the relief it affords to pain and discomfort.

The above treatments may be associated with any other measures which may be found beneficial in the management of this disease. Physical methods are, however, highly suggestive of those reparative efforts which nature seeks to make in the limitation and control of the bacterial invasion of tuberculosis, and deserve to be faithfully tried.

Asphyxia.— *Induced Currents.* A large pad should be applied to the phrenic nerve and another to the insertion of the diaphragm along the anterior wall of the thorax. The treatment may be associated with artificial respiration or may be alternated with it.

Direct Currents. These may be employed with the electrodes similarly placed and interruptions three times per minute, gradually increasing until resuscitation occurs.

Asthma.— *Paroxysm. Induced Currents.* Erb recommends the use of induced currents. The electrodes are placed upon opposite sides of the neck on a line running from the angle of the jaw to near the

sternum. The treatment should last from one quarter to one half hour. The current may be passed through the neck to the cardiac region.

Direct Currents. Here an electrode is placed over the pneumogastric nerve, about the middle of the inner border of the sterno-cleido-mastoid. The indifferent electrode may be placed over the sternum opposite the third cartilage. Weak currents should be employed.

Wave Current. This method seems to have produced admirable results. A metal electrode having an area of about twenty-five square inches is placed over the sternum, and the treatment continued for thirty minutes.

Interval. The above methods may be used for interval treatments also.

The High Frequency Vacuum Tube. This has in the hands of the author served to prevent recurrence of the paroxysms and give permanent relief to this distressing disorder.

Auto-Condensation. Dr. Gamlin has reported a number of cases successfully treated by both local and general applications of high frequency currents. In one case attacks were prevented by brief treatments upon the auto-condensation couch.

Reflex Conditions. It must not be forgotten that in some instances nervous asthma seems to result from reflexes from distant centers, as from adenoids or other nasal conditions. It is not necessary to remark that all such probable sources of asthmatic troubles should be carefully examined and removed.

Arc or Incandescent Light. This treatment is admirably adapted to relieve a paroxysm. It may also be advantageously employed as an interval treatment.

Hiccough.— This may be successfully treated by placing the anode on the epigastrium or along the line of attachment of the diaphragm, and the kathode over the phrenic nerve along the outer edge of the sterno-cleido-mastoid just below its middle. An alternative treatment is to pass the current through the body at the level of the diaphragm. The currents employed may be direct or induced. The direct current may be interrupted.

Tachycardia.— *Direct Current.* A careful study of the causes of this trouble must first be made. Upon the assumption that the inhibitory function of the pneumogastric is in some way impaired, the direct current has been successfully applied to the vagus along the border of the sterno-cleido-mastoid, first on one side and then on the other. These treatments should be continued during the intervals between attacks and should last for a few minutes.

Angina Pectoris.— In regard to this painful disorder, Dr. N. S. Davis, Jr., says: "Galvanism certainly promises more than medicinal treatment. It usually gives very prompt relief, and its persistent use has many times appeared to produce a permanent cure.

Direct Currents. Eulenburg's method is to place a large pad over the heart and sternum and the negative on the lower cervical vertebræ. Von Heubner placed the positive electrode in the supra-sternal

fossa, and the negative upon the cervical lymphatic ganglia, first on one side and then on the other. He employed weak currents at first, increasing them according to the tolerance of the patient. The treatment should last from one to five minutes.

Arc Light. Hasselbach and Jakobaüs, in the *Berlin Klin. Wochenschr.*, No. 39, 1907, have reported improvement in cases affected with this disorder when submitted to the action of arc light baths. The blood pressure was lowered and the respiration and heart action were notably improved.

Arterio-Sclerosis.— It is not claimed that any method of physical therapeutics can undo the damage already inflicted upon the coats of the blood vessels by the degenerative processes that have manifested themselves in the circulatory system. It is believed, however, that in many cases the sclerotic changes occurring in the arterial system are the manifestation of a compensatory process brought about by a continuous or intermittent high arterial tension. In other words, hypertension may be set down as a cause of arterio-sclerosis. While, therefore, it may not always be possible to determine at the beginning of treatment whether the arterio-sclerosis in any given case is an effect or a cause, it is well to resort to methods which will influence hypertension with the hope of correcting further sclerotic changes.

Auto-Condensation. There is now a large body of evidence tending to show that the blood pressure is reduced by auto-condensation. Sailer and Papiermeister, in summarizing the result in thirty-four

cases, say that the pressure fell after cessation of treatment to below normal, and remained low for at least three hours after the termination of the sitting. These results have frequently been verified in practice.

High Frequency Vacuum Electrodes. Dr. Arnold, in reporting a number of cases treated by high frequency vacuum electrodes, concludes that " high frequency electricity may be so applied as to reduce blood pressure in almost all cases."

Incandescent Light Baths. Cleaves regards incandescent light baths of much value in arteriosclerosis, but considers them unsuitable in extreme cases.

Bronchitis.— *Electric Arc Baths.* Excellent results are secured by exposing the patient to the full power of the electric arc light. Indeed all forms of light treatment are useful here, though the penetrating action of the actinic rays is productive of the greatest benefit.

Blue Light. The screened arc light is highly beneficial.

High Frequency Currents. Hedley finds that these currents in the form of an effleuve effectually subdue the cough and combat the atonic dilatations which favor a return of the catarrhal condition upon slight exposure to changes of weather.

Bronchiectasis.— *High Frequency Currents.* Dr. Gamlin, in the " Archives of the Roentgen Ray," reports two cases in which the alleviation was remarkable from the use of high frequency currents. The treatments described above may also be used.

CHAPTER VII

DISEASES OF THE ALIMENTARY SYSTEM

Constipation.— We must, of course, ascertain the cause, if possible, and by appropriate treatment remove it. Thus where constipation depends upon the presence of fissures or hemorrhoids, these conditions should first receive attention. Bowel training must be instituted where the habit of postponing the call to defecation has been acquired. Where alimentary constipation exists, due to improper nutrition, a proper diet containing a suitable proportion of non-constipating elements must be carefully supplied with an abundance of water. In constipation due to continued use of drugs the obvious treatment is abstinence from purgatives. In neurogenous or psychogenous types of constipation, where this trouble is associated with nerve-destroying conditions, the manner of living must be changed. Boas mentions four varieties of habitual constipation; (*a*) atonic spastic; (*b*) spastic; (*c*) a form characterized by fragmentary bowel movements. and (*d*) a form followed by stercoral diarrhea.

It must be apparent that for the treatment of this condition the patient needs to be under the supervision of the physician until cured. A cure may be said to have been attained when the patient has a

natural movement at least once in twenty-four or forty-eight hours. In bringing about this result the most important part of the treatment is, unquestionably, dietetic, after the removal of any associated condition which may tend to prolong the trouble, and to which reference has already been made above.

When, now, the patient has been properly started upon his treatment, the following subsidiary treatment, according to Boas, tends to hasten the establishment of normal movements of the bowels, *viz.* electricity, vibratory stimulation, and hydrotherapy.

Among these he ranks electricity first, recommending the employment of the induced current applied by means of broad, flat electrodes to the abdomen or by means of a soft, rectal sound introduced into the rectum.

So far as possible the particular type of constipation affecting the patient should first be ascertained in order to make an intelligent selection of the treatment demanded.

The author has found the following methods of treating constipation of most value:

Direct Current.— Thus where constipation is due to a relaxation of the abdominal muscles the application of the direct current, by means of well-moistened pads over the abdomen, along the course of the colon from the right iliac fossa to the sigmoid flexure, serves to revive the tone of the weakened muscles. The current should be interrupted about twenty-five times per minute.

Where it is due to atony of the muscular coat of the bowel, a large pad attached to the positive pole should be placed beneath the lumbar vertebræ, the patient being in the recumbent position. The current should be interrupted about twenty-five times per minute, and the negative electrode, placed upon the abdomen, should be moved from right to left as above described. The treatment should be continued ten minutes and occur daily until improvement begins.

Static Wave Current.— Here the positive pole of the static machine is connected with a plate of flexible metal, eight by ten inches, placed upon the abdomen. The treatment should be given daily and continued twenty minutes.

The same current may be administered to the patient in a sitting position by means of a rectal electrode.

Static Induced Current.— This current is similar in effect to the wave current, but much more effective. One pole may be on the abdomen, the other in the rectum or on the back.

The static currents are especially indicated where peristalsis is below normal. The effects of these treatments may be enhanced by gradually and regularly moving the sliding rods of the static machine backward and forward, thus producing a swelling or undulating current.

Sinusoidal Currents.— Of much value in the treatment of constipation due to deficient peristalsis are sinusoidal currents. The advantage of

these currents is that they produce contractions of the muscular coat of the bowels similar in character to normal peristalsis. The sensory element is largely eliminated, owing to the gradual change in tension as graphically expressed by the sinusoidal curve. An apparatus, therefore, which produces a true sine curve is better than one which only approaches it. Such an apparatus should likewise be susceptible of adjustment, so that the number of alternations per minute may be reduced to sixty or less. Better results are secured by slow alternations ranging from twenty to sixty per minute, than from those which are more rapid, the normal peristalsis being a comparatively slow process.

Mechanical Vibratory Stimulation.— Associated with this treatment may be mechanical vibratory stimulation. The soft vibratode with medium stroke should follow the course of the colon, making somewhat deep pressure. The patient should then lie prone and the ball vibratode be introduced between the transverse processes of the third and fourth lumbar vertebræ, in order to awaken the centers of defecation in that area. The pressure should be moderate and the amplitude of vibration medium. The vibrator should remain in each position but a few seconds. In like manner the vibrator may be placed over the seventh, eighth, and ninth dorsal vertebræ to stimulate the action of the liver.

No disease can be cured more readily than constipation by one or more of the methods outlined above. It is the rule of the author gradually to

discontinue the use of purgatives. In many cases, however, there will be no need of further medication after the first treatment. By combining the use of the direct current with vibratory stimulation the author, in a single treatment, permanently cured a patient seventy-two years of age of constipation of long standing. In obstinate cases it may be necessary to associate several of the methods above described and continue daily treatments for a considerable length of time. If, however, each case is intelligently managed with a careful scrutiny of all the causes which tend to delay recovery, the result can never be in doubt.

Stricture of the Esophagus.— This may be (*a*) organic or (*b*) functional. In the treatment of the former condition little aid has been derived from internal or external applications of electricity. The latter condition may be greatly benefited by

The Direct Current. The kathode is placed over the cilio-spinal center, the anode just above the sternum, or near the inner border of the sterno-cleido-mastoid muscle. Should this fail, an insulated flexible electrode with metallic tips should be introduced into the esophagus and gently pushed against the contracted area, the indifferent electrode being placed upon the back.

Electro-Cautery. In obstinate cases the electro-cautery applied to painful spots along the spine has proved effective.

Spasm of the Pharynx. This may be relieved by

The Direct Current applied externally, one electrode upon each side of the pharynx, or internally by means of an insulated electrode applied directly to the constrictors of the pharynx.

Induced Current. This current is also serviceable in this condition.

Paralysis of the Esophagus.— This may occur in hysteria, diphtheria, and in alcohol and lead poisoning. In hysteria the advantage would doubtless result largely from the psychic impression produced by the application of a mysterious or dreaded agency. Conjoined with proper associated treatment electricity is of value in the toxemias of alcohol and plumbism and particularly in diphtheria. For this purpose we may employ

The Induced Current. This may be administered generally or locally by means of an electrode applied directly to the pharyngeal membrane.

The Direct Current. Here the current may be applied externally, one electrode being placed upon each side of the pharynx. The sitting should be of brief duration and the current should not be interrupted.

Dilatation of the Esophagus.— This condition is associated with strictures and diverticula, though cases may occur, rarely, in which there is a somewhat uniform dilatation of the whole tube without grave symptoms.

Diverticula do not lend themselves to electrical treatment. Dilatations which do not originate in stenosis may be beneficially treated by

The Direct Current. A flexible electrode is introduced into the esophagus for the purpose of stimulating the muscular walls, and gradually moved upward and downward. The indifferent electrode should be placed upon the sternum, and a current of from three to five milliamperes employed. The sitting should not exceed five minutes.

Induced Current. This may be applied by means of pads placed upon the spine and sternum, and may be supplemented by the direct current similarly applied.

Gastralgia.— This is a symptom, not a disease. Whether the disorder is ever purely functional in character may be doubted. Yet it is frequently impossible to ascertain a pathological basis for gastric pain. In these cases, therefore, where the pathology is not understood, it is certainly quite as rational to use electricity as any other method of relief, more especially as electric treatment is found to be of extreme value.

Direct Current. One pad is placed upon the spine, the other over the epigastrium. This current is found to be of most service in those cases where pressure over the epigastrium produces pain.

Induced Current. The pads are similarly placed. This method is applicable in those cases where pain is relieved by pressure.

Static Wave Current. This will afford relief in obstinate cases.

Nervous Dyspepsia.— This condition is expressed by a variety of terms, as gastric neurasthenia,

or atony of the stomach. It is impossible to discover a pathological alteration in the structure of the stomach. It is, therefore, permissible to consider the disorders included under these designations as functional. In respect to treatment Strumpel remarks, " We have repeatedly found electricity valuable," though he is not prepared to deny the influence of suggestion.

Arc Light Baths. These are highly useful, performing the same role as in general neurasthenia, increasing the hemoglobin, stimulating elimination, and promoting nutrition. They should be administered daily at first and later at increasing intervals, and should continue from thirty minutes to an hour.

Direct Current. This may be applied by means of pads placed upon the epigastrium and dorsal spine. Better results are secured by slow interruptions of a mild current.

Induced Current. A large pad is placed over the epigastrium and a similar pad is placed over the dorsal spine. The former is kept in constant motion to avoid muscular contractions, which are exceedingly painful.

Acute Gastritis. This condition is not suited to electrical treatment.

Chronic Gastritis.— This disease is characterized by diminished normal gastric secretions, with an increase of mucus. There is, likewise, reduced peristalsis. There is an alteration, therefore, in both the secretory and motor functions of the stomach. There can be little doubt that the direct current promotes

nutrition by the electrolytic processes which it sets up, and that both the direct and the induced current promote peristalsis. It would, therefore, be proper to employ these currents in this intractable trouble, with the expectation of improving both the secretory and motor functions of the stomach.

The High Frequency Vacuum Electrode may be placed over the epigastrium for the purpose of improving the nutrition of the organ.

Gastric or Duodenal Ulcer.— This disorder is not benefited by electrical treatment.

Carcinoma.— In inoperable cancer of the alimentary tract the physician should unquestionably expose the patient to the X-ray. The analgesic effect of the X-ray has been demonstrated in the experience of all physical therapists. Thus, if the arrest of the disease is not secured, the patient is likely to be rendered more comfortable and life prolonged. *Radium* may be similarly employed where it is possible to introduce it into the esophagus, stomach, or rectum.

Radium Emanation. Recent researches following the discovery by Rutherford that cocoanut charcoal absorbs with great avidity the radium emanations opened a new field for experiment in the management of this formidable disease. Since all of the phenomena of radium are manifested by the emanation, it can readily be seen that the introduction of measured doses of charcoal charged with the emanation into the stomach would theoretically afford an admirable method of bringing this energy into close contact with the diseased areas.*

* See Dr. D. Shober, in *Journal of the American Medical Association* Aug. 21, 1909.

Dilatation of the Stomach.— Where this results from carcinoma or from stenosis of the pylorus following ulcer of the stomach, no relief can be obtained from electricity. There are, however, many cases due (*a*) to excessive eating and drinking; (*b*) to impaired mobility of the muscular layer, sometimes existing from birth; (*c*) to a chronic gastritis, (*d*) to a constitutional disorder, as anemia, or (*e*) to a severe illness. In all of these cases appropriate treatment associated with electricity may produce remarkable results.

Induced Current — Internal Treatment. Einhorn's electrode, consisting of a metallic conductor, covered with a hard rubber capsule perforated at many points, is attached to a flexible insulated wire. This is readily swallowed by the patient. The current should be graduated and administered with much care. The indifferent pad may be placed upon the abdomen. The results of such treatment are increased gastric secretions with progressive shortening of the muscular fibres of the stomach.

External Treatment. This treatment is supplemented by applying the pads to the dorsal region and the epigastrium. In these cases the induced current of quantity has been found to be most advantageous.

Vomiting.— This is a symptom, and its causes must be carefully sought. Where it has its origin in an organic condition, as, for instance, ulcer or cancer of the stomach, or cerebral inflammation or pressure, electricity will be of little value. In ulcer of the stomach it is likely to aggravate the condition. This fact

may serve as a useful method of differential diagnosis between ulcer and those neurotic conditions in which electricity may be of distinct advantage. In the neuroses nausea is generally absent, and here electric treatment has been found to be of distinct value.

Direct Current. The anode should be applied to the epigastrium and the kathode to the nape of the neck. Five to twenty milliamperes may be employed.

Induced Current. The electrodes may be similarly applied, or the method of general faradization employed.

Catarrhal Enteritis — Chronic Diarrhea. — Both Strumpel and Rockwell regard electricity as valuable in this stubborn complaint.

Induced Current. The pads are placed upon the abdomen and back. This may be alternated with general faradization. The treatment must be continued with much persistence.

Light Treatment. The nude body should be exposed in the cabinet to the rays of the arc lamp at frequent intervals, either replacing or following electric treatment.

Hepatitis — "*Biliousness.*" This is ordinarily readily corrected by proper dietetic and hygienic regulations, assisted by the administration of proper medicines. In connection with these the incandescent bath may be employed which, by the depletion of the viscera through profuse sweating and active hyperemia of the surface, quickly restores the normal balance of the system.

Jaundice.— This symptom of numerous condi-

tions should direct attention to the cause. Where it is due to obstructive or mechanical causes little relief may be expected from electric treatment. When, however, it follows spasmodic stricture of the bile ducts, or obstruction due to inspissated bile or a mucous plug, it is possible that the direct or induced current may exert a favorable influence. Where there is obstruction to the flow of bile, the fecal discharges are clay colored. This fact furnishes a differential diagnosis between jaundice due to obstruction and those cases which have their origin in a sudden disturbance of the nervous system, as grief, anger, or fright.

Cases which are non-mechanical in their origin are benefited by the

Induced Current. This is applied by the general faradization method, and has produced excellent results, rapidly abridging the period of recovery.

Light Baths. In the cases produced by non-mechanical causes, light baths are highly efficacious, speedily removing the bile pigment from the skin, relieving pruritus, accelerating the abnormally slow action of the heart, relieving mental depression and rapidly improving metabolism. For this purpose the incandescent light bath is probably preferable to the arc light bath.

Gastroptosis, Enteroptosis, Nephroptosis. — These diseases result from repeated pregnancies, ascites, tight lacing, rapid loss of flesh, or a general weakness in the musculature, due to sedentary habits or constitutional debility. The choice in treatment

lies between artificial support of the sagging viscera by means of corsets, resort to surgery for restoration of the kidneys to their normal position, or the institution of remedial measures which restore to relaxed ligaments and muscles the strength needed to hold the abdominal organs in their proper position. Corsets are almost uniformly unsuccessful in supporting organs which have been loosened, or which have wandered from their proper position. This is especially true of movable or floating kidney. Nephropexy is in like manner a most unsatisfactory operation, the kidney frequently detaching itself after operation from its artificial supports. It is, therefore, incumbent upon the physician to discover methods which will offer a more encouraging reward for his effort than those hitherto employed. This must include a general improvement in health, since it is entirely probable that without the coincidence of impaired health the other causes enumerated above would not ordinarily suffice to bring about a sphlanchnoptosis. To effect a general improvement in health, in addition to suitable dietary regulations and graduated exercises,

General Vibratory Stimulation should be produced along the spinal centers from the first dorsal to the first sacral vertebra, with the ball vibratode, making deep pressure between the transverse processes for a few seconds. Care should be taken not to prolong the treatment, and thus produce inhibition. For the purpose of exercising the abdominal muscles the sponge vibratode should be carried backward

and forward over the abdominal area for a few minutes.

Sinusoidal Current. This current, owing to its slight sensory effect, is admirably adapted to furnish passive motion to weakened muscles, supplying exercise which the patient might be too feeble to obtain without such aid.

Arc Light Baths. These should be administered for the vast assistance which they furnish to metabolism. They should be given daily in conjunction with general vibratory stimulation and the sinusoidal current. The above treatment meets all the indications for improvement in this rebellious condition, and must prove of much greater utility than artificial supports, which still farther rob the natural supports of needed strength, or surgical procedures, which too often, at great risk of life, fail to accomplish the end desired.

Cirrhosis of the Liver.— It could scarcely be hoped to exert much effect upon the pathological process presented by this disease. Yet these cases are undoubtedly relieved by appropriate physical treatment. These include the use of the

Induced Current by the general faradization method, and

Arc Light Baths. The general effect produced by exposure of the nude body to the arc light is to increase the action of the kidneys and to stimulate the undamaged liver cells to greater activity.

Diabetes Mellitus.— Careful regulation of diet must not be neglected. The degree of toleration of carbohydrates must be ascertained and a care-

ful study of the effect of different carbohydrate foods made, in order to determine the variety which is best suited to the particular case in hand. Thus the Van Noorden " oatmeal cure " works admirably in some cases, enabling the patient to secure a large intake of carbohydrate food without glycosuria.

High Frequency Currents. Many reports from physicians of unquestioned standing have been presented to show the value of these currents in diabetic conditions. In many of these cases dietetic measures have not been suspended during the continuance of the electrical treatment, so that the results are lacking in that certainty which they might otherwise possess. In other cases no information is given upon this important point. Auto-condensation or auto-conduction has been usually employed. Favorable reports have been made by Chisolm, Williams, D'Arsonval, Charin, Reall, De Renzi, G. S. Viaus (Turin), Vinaj, Netta, Boedeker, De Kraft, etc.

Static Wave Current. Snow recommends the application of an electrode five by eight inches over the pancreas, with a spark gap of from four to eight inches.

General Electrization by Electric Baths. Jones has noted a marked decrease of sugar on the days when electric baths were given.

Direct and Induced Currents. Rockwell reported a case in which great improvement resulted from " general faradization " and " central galvanization."

Electric Arc Baths. These should be employed

in every instance for their notable effect upon nutrition. The oxidizing action of light tends to a reduction of sugar in the urine, and a decrease of acidosis.

Mechanical Vibratory Stimulation. Brief application of the ball vibratode should be made over the centers in the spinal cord, affecting the action of the liver and other abdominal viscera.

NEPHRITIS.— *Induced Current.* Dietetic, hygienic, and medicinal methods have been most discouraging in the management of this disease. It ought not, therefore, to excite surprise that attention is turning toward physical methods with the hope of arresting or curing the pathological processes underlying this malady. Rockwell once reported a case as cured, in which both albumin and hyaline casts had been present in the urine. At first regarding this disease as chronic nephritis, he concluded later that it could have been only hyperemia of the kidneys. His method of treatment had been " general faradization."

Static Treatment. Neiswanger has reported twenty consecutive cases of Bright's disease, in which sixty per cent were permanently relieved; ten per cent partially relieved, and thirty per cent not benefited. In these cases the diagnosis was clear and well attested. The treatment employed was the negative head breeze for fifteen minutes, followed by positive insulation for the same time. The wave current to the spine was alternated with the head breeze. Such results should encourage physicians engaged in physical therapeutics to undertake these practically

abandoned cases with the hope of affording at least some measure of relief.

Incandescent Baths. These are valuable in nephritis, because they produce diaphoresis and divert the blood from areas of congestion to the surface of the body. They likewise, by profuse sudation, eliminate toxic products imperfectly excreted by the kidneys. These baths should be administered daily, or in alternation with static treatment. After a period of exposure to the incandescent bath the patient should be removed to the electric arc cabinet, carefully covered, and allowed to recline for a time.

Mechanical Vibratory Stimulation. Following an incandescent or arc light bath a general application of the sponge vibratode to the body and the ball vibratode to the spine may be made.

Leukemia.— *The X-ray.* It is admitted that with the exception of arsenic, medicaments are valueless. This drug occasionally exerts a correcting or temporarily curative effect. We may then welcome any agency suggested by physical therapeutics which offers a prospect of relief.

The first results from the employment of the X-ray have been highly encouraging, though it would appear from a survey of the literature of this disease that the number of permanent cures has not been large. Stengel and Pancoast, in the *Journal of the American Medical Association*, April 25, 1908, fix the number of permanent cures at 8.7 per cent; primary symptomatic cures not permanent 36.25 per cent; initial improvement without permanent

results 30.43 per cent; cases in which there was little or no favorable reaction 24.64 per cent. It is very evident, however, from these figures that a profound influence is exerted upon the disease by this new agency, even though the net result of permanent cures is not large.

There are three types of leukemia which receive their name from the variety of tissue principally affected, namely: splenic, myelogenous, and lymphatic. In each variety, however, all of the structures are more or less affected. Assuming that the first organ or structure involved is the bone marrow, which opinion finds an increasing number of supporters, the authors urge that the chief areas demanding irradiation are those which contain bone marrow. It is true that a symptomatic cure as evidenced by reduction in the size of the spleen and restoration of the normal ratio between white and red corpuscles may be secured by irradiating the spleen, but as this organ is not the source of the disorder the cure is not permanent. Nevertheless, both the spleen and the disordered lymph nodes are to receive a share of attention.

Their method embraces the following points: Daily exposures lasting fifteen minutes of different areas of the body to a tube with a four-inch equivalent spark gap. Beginning with the feet the different sections of the body are successively and regularly treated, the spleen being avoided in the earlier applications. Though the number of cases treated has not been large, the authors claim a greater permanence in the results secured by this method.

Pseudo-Leukemia — Hodgkins's Disease.— *X-ray.* Numerous cures have been reported in the treatment of this otherwise fatal complaint.

Mucous Colitis.— This condition is improved by general electrization by means of the electric bath, with the direct or sinusoidal current. For the correction of the constipation incident to this condition pads placed in the iliac fossæ carrying thirty or more milliamperes for periods of eight to ten minutes have been employed with excellent results.

A successful treatment for this condition was reported in the *Lancet*, Nov. 4, 1905, in which after thorough lavage the bowel was irrigated with a 0.1 per cent solution of silver nitrate and a current of from fifteen to twenty milliamperes passed for fifteen minutes by means of a copper wire connected to the rectal tube.

CHAPTER VIII

DISEASES OF THE SKIN

Acne Vulgaris.— The classic procedures, including the removal of comedones, thorough cleansing of the skin, the correction of dietetic errors, and the general improvement of the health should be carefully carried out. Supplementary to these procedures are:

(1) *The X-ray.* Excellent results may be secured by successive irradiations, the time and number of exposures to be determined by the progress of the case.

(2) *Light.* The concentrated energy of the electric arc and the electric arc bath are considered by Cleaves the most useful procedures in acne vulgaris. Since it is desired to produce a systemic condition, the electric arc bath is to be preferred. The concentrated energy of the electric arc may be associated with a compressor. Finsen reports a number of cures.

(3) *High Frequency Vacuum Discharges.* Very encouraging results follow in some cases from high frequency discharges administered by vacuum electrodes.

(4) *Ultra Violet Light.* Acne vulgaris and acne rosacea have both improved under the influence of the ultra violet light.

(5) Other procedures of utility are the continuous current, especially where the lesions are sluggish, electrolysis in the severe pustular types, and central galvanization and faradization.

ACNE ROSACEA:

(1) *Electrolysis.* This disfiguring disease may be treated successfully by electrolysis. For this purpose a jeweler's broach pointed like a trocar is well adapted. The needle transfixes the dilated blood vessel in several places. The process is continued until the vessels are thoroughly destroyed. A current of from one to three milliamperes is sufficient. The active pole is of course the negative.

(2) *Concentrated Arc Bath.* Supplementary to the above treatment, concentrated light energy may be employed. Lerreode has reported a number of cases.

(3) *Direct Current.* The direct current is also of great value, as are the other procedures mentioned under acne vulgaris.

ALOPECIA:

Several dermatologists have used static electricity with success. The crown breeze, in the experience of the author, has resulted in a marked increase in the health and vigor of the hair. The patient should be connected with the positive pole of the machine. It is, of course, unnecessary to say that where the scalp has become tense and shiny the hair follicles are destroyed and are incapable of producing hair under any treatment.

Direct Current. The negative pole attached to a

well-moistened pad may be applied to the scalp every other day with a current of five to ten milliamperes. The positive pole may be held in the hand or placed on a convenient spot upon the body.

Alopecia Areata:

(1) *High Frequency Vacuum Discharges* have been found useful.

(2) *Phoresis.* A copper electrode used as the anode is efficacious, especially where the disease has a parasitical origin.

Dr. H. Marquès reported, in 1908, to the electrical section of the Congrès de Clermont-Ferrand de l'Association Française pour l'avancement des Sciences, an interesting case of alopecia areata, in which an area of the size of a five-franc piece was treated by the application of the positive pole attached to a pad saturated with a ten per cent solution of zinc chloride. The current had a strength of fifteen milliamperes, and was continued for thirty minutes. In twelve days a large number of hairs appeared upon the bald area. Unhappily the patient left the hospital, and further treatment was discontinued.

(3) *Ultra Violet Light.* This light, furnished by a condenser spark, arc, or Kromayer lamp, has been highly successful in restoring the growth of hair.

(4) *Concentrated Energy of the Electric Arc.* In Finsen's first report of his work, published in England and America, he notes several cases which were cured by the concentrated energy of the electric light.

(5) *The Direct Current.* Apparently this is the least useful procedure in the treatment of this disease.

ANGIOMA:

Under this head may be discussed three types, *viz.:* (*a*) *Naevus vasculosus* or birthmark. (*b*) *Telangiectasis* or *naevus* occurring in adult life. Acne rosacea is a form of this disease. (*c*) *Angioma cavernosa.*

Naevus Vasculosus, or birthmark, may be destroyed by a tattooing process. A fine needle attached to the negative pole and inserted vertically into the skin. It is a slow and somewhat painful process, but produces good results. Not more than four milliamperes should be used.

(1) *High Frequency Spark.* Dr. Bergonie employs the high frequency spark. This method, followed by Dr. H. Lewis Jones, is believed by him to be by far the most efficient in removing these stains. The X-ray has produced excellent results.

(2) *Radium* is said to be more successful than the X-ray in the management of these cases.

Telangiectasis. The treatment here is essentially the same as that already described under acne rosacea. However, in the larger varieties two or more needles may be employed arranged parallel to each other in a specially constructed needle holder, in which the needles are alternately positive and negative. These are introduced parallel to the skin, and currents running as high as twenty, thirty, or forty milliamperes may be employed.

(1) *Electro Cautery.* Dr. H. Lewis Jones, who has recently reported upon sixteen hundred cases of naevus treated by electrical methods, regards the

electric cautery as the best treatment in these cases. He is careful, as in naevi of the scalp and forehead, to carry the point of the cautery down to the bone, having noted that this type of naevus frequently involves the pericranium.

(2) *X-ray and Radium.* These may be employed as in the preceding variety.

(3) *Zinc Phoresis.* In the case of naevi, which are largely subcutaneous, excellent results may be obtained by the use of zinc needles connected with the positive pole.

(4) *Arc Light.* In both these varieties of naevus concentrated light energy is useful, the deep red color being reduced in the former, and the arborization in the latter.

Angioma Cavernosa. Here there are comparatively large chambers filled with blood and separated by partitions of fibrous tissue. These, if not too large, may be cured by the electro-cautery or electrolysis. Where a naevus of this type is larger than one half inch in diameter it should be referred to the surgeon.

TINEA:

The different forms of tinea readily lend themselves to electrical treatment. They are five in number, and are the result of the growth of microscopical vegetable organisms in or upon the skin. These belong to the class of hyphomycetes. The three varieties of ringworm of the scalp, beard, and body are produced by the growth and development of the *tricophyton. Tinea favosa* is produced by the *achorion Schönleinii*, and *tinea versicolor* by the

microsporon furfur. These organisms are all fungi, producing a branched network of threads or *mycelium* and spores.

(1) *Phoresis*. From the nature of these diseases it can readily be perceived that they lend themselves easily to phoresic treatment. For this purpose an electrode saturated with a three to five thousand solution of corrosive sublimate should be attached to the positive pole and applied to the affected area. The current should not exceed eight milliamperes. The areas to be treated should previously be cleansed, the crusts having first been carefully removed. It would seem that a salt of copper would be equally efficacious.

Of these diseases, *tinea favosa* is not common in this country.

Tinea versicolor or chromophytosis, affecting most frequently patients afflicted by phthisis or hyperidrosis, is not in itself a serious affection.

Of the three forms of diseases produced by the *tricophyton*, *tinea capitis*, or ringworm of the head, is most serious. *Tinea barbæ*, or ringworm of the beard, or barber's itch, is also exceedingly obstinate. *Tinea corporis*, or ringworm of the body, is quickly responsive to treatment by ordinary drug medication. The method above described affords an admirable means of quickly destroying by phoresis the parasitic cause of this group of unsightly and contagious diseases.

(1) *X-ray*. *Tinea capitis* and *tinea barbæ* may be successfully treated with the X-ray. Sabouraud has described a method of timing the exposure by means

of pastilles of platino-cyanide of barium, so that the dosage may be so adjusted as to insure depilation without producing dermatitis.

(2) *Concentrated Light Energy.* This is applicable to the treatment of all these varieties of parasitic disease, and numerous cases have been reported in which cures were effected by the concentrated energy of the electric arc.

CARBUNCLE:

(1) *The direct current* has been successfully employed to abort phlegmonous inflammations. Where they have, nevertheless, advanced to the stage of necrosis, recourse may be had to the electro-cautery, which is both aseptic and bloodless. The alternative method is excision and curetting.

(2) *Ultra Violet Light.* Several cases have been reported in which carbuncle has been aborted by the ultra violet light.

Zinc Phoresis.— An excellent method for the management of these cases after incision is to introduce a zinc electrode attached to the positive pole into the wound. This quickly sterilizes the necrotic tissues, and rapidly abridges the period of recovery.

The same method may be employed to abort a carbuncle. The sterilization is absolute. Cocaine may be employed to relieve pain and the strength of the current will depend upon the size of the lesion. A current of ten milliamperes for ten minutes may be employed with safety.

Elephantiasis — X-ray. Dr. Walter B. Adams, of Beirut, Syria (*Journal of Cutaneous Diseases*, Oct., 1908), has reported great improvement in the case of

a Syrian woman afflicted with this disease, by employment of the X-ray.

CICATRICES.— These may occur in three forms, *viz.:* (*a*) atrophic or depressed, (*b*) hypertrophic, and (*c*) telangiectatic. For all of these types electrolysis is the best treatment. In the atrophic or depressed type the object is to remove the superficial layer of epithelium, and thus by means of dressings to bring up the granulating tissue to the level of the surrounding skin. It is a tedious process and not likely to be undertaken in multiple scars resulting from small pox.

Where the hypertrophic scars are large it may be preferable to employ plastic surgery.

In the telangiectatic type the same method is employed as described under "angioma" (*page* 413).

KELOID:

This is not strictly a hypertrophic cicatrix, since it is believed to occur spontaneously without previous traumatism, though this point is not positively proved. It is characterized, at any rate, by an extension of connective tissue beyond the site of the original injury, if due to traumatism, often assuming the form of arms having a crablike appearance.

HYPERTRICHOSIS OR SUPERFLUOUS HAIR:

(1) *Electrolysis.* To remove superfluous hair any form of battery may be employed; the Grenet, gravity, Leclanché, or dry cell, if the commercial mains are not available. For this purpose, if a Grenet battery is employed, from two to ten cells may be used, the larger number being rarely necessary. In any event an accurate milliamperemeter should

always be introduced into the circuit. The current strength may run from one to six milliamperes, the higher strength being not usually necessary.

The positive pole should be attached to an electrode of cotton, spongiopiline, or other material capable of absorbing fluid. It should be as large as the hand, and preferably saturated with an aqueous solution of common salt or sodium bicarbonate. Upon this the patient may place the hand during the process of epilation. The other pole should be attached to a needle holder containing a Hayes bulbous needle. The patient should recline on a table, and a good light, furnished by a forty candle-power electric lamp supported by an adjustable bracket, employed to give thorough illumination to the area which is to be operated upon. A magnifying glass is frequently useful. This may be supported upon the forehead or attached to the needle holder. Finally, an epilation forceps is needed.

Hairs are rooted at different distances below the surface, varying from one thirty-second to one fourth of an inch. It is interesting to study for a moment the structure of the investing membranes of the hair. These consist of two coats, the outer or dermic coat, and the inner or epidermic coat. The former is made up essentially of the two layers of the corium, namely, the papillary and reticulated layers. We are particularly concerned, however, with the inner or epidermic layer, because this frequently adheres to the hair when it is removed, and presents a white, silvery appearance. This consists of two *strata*, called respectively the outer and the inner root sheath. The outer root

sheath corresponds with the Malpighian layer of the epidermis. The inner root sheath consists of the delicate cuticle next to the hair shaft, then of one or more layers, called Huxley's layer, and finally of another layer of horny cells, called Henley's layer.

The art of removing hair by electrolysis cannot be acquired by mere description of the technique employed, though this may give valuable assistance. How far to introduce the needle, how long to let it remain, how much frothing should be permitted, and how not to leave a scar are some of the problems which experience only can solve completely. Some operators can remove from sixty to one hundred hairs in an hour, though many patients cannot endure so long a treatment.

The question of reducing pain is an important one. For this many methods have been suggested. One operator uses a five per cent solution of carbolic acid, another removes four hairs at the angles of a quadrangle, and then covers the area with a ten per cent solution of cocaine, employing phoresis to drive in the anesthetic; another uses a four per cent solution of cocaine in guaiacol with phoresis; still others work without local anesthesia, directing the patient to remove the hand from the positive electrode when the needle is removed, and not replacing it until the needle is again introduced.

Each operator acquires his own technique after adopting and rejecting various procedures that have been presented to his attention.

(2) *X-ray.* Superfluous hair may be successfully removed by the X-ray. For this purpose num-

erous exposures are necessary with great vigilance in order to avoid a destructive dermatitis. The danger connected with the treatment and the uncertainty as to the number of exposures necessary to effect the purpose in view tend to limit the usefulness of this method. Moreover, the tendency to recurrence diminishes the enthusiasm of both patient and operator.

Carcinoma of the Skin.— This takes several forms, *viz.*: *Carcinoma lenticulare*, which occurs frequently in the scar following an operation for mammary cancer; *carcinoma tuberosum*, which may be primary or secondary to cancer of other organs, and *carcinoma melanoides*, which results frequently from the malignant degeneration of a mole. These should all be promptly removed at their first appearance either by the electro-cautery or by electrolysis. In fact, removal is so easy by these methods, and the danger from delay is so great, that all excrescences, wherever appearing on the body, should be promptly extirpated. Moles in particular are liable to malignant degeneration.

Epithelioma.— This occurs by preference near or at the juncture of the skin and mucous membrane, being seen oftenest on the face about the eyelids or nose, though it may appear also upon the nasal, buccal, vaginal, and rectal mucosæ. The most familiar type of this disease is rodent ulcer. This is benign at first and may exist for years without causing trouble.

Electro-cautery or Electric Needle. This disease may be readily cured in its incipiency by the use of the electric cautery or electric needle, which should de-

stroy enough of the contiguous tissue to prevent recurrence from undamaged cells.

Zinc Phoresis. This method was introduced by Leduc. An electrode saturated with a solution of zinc sulphate, twenty grains to the ounce, is attached to the positive pole and a current of two milliamperes per square centimeter is allowed to flow for about fifteen minutes. The results secured by this method have been highly satisfactory.

Radium. A tube of radium may be applied to the surface of the ulcer for thirty or forty minutes. A reaction occurs in the neighborhood of the fourteenth day, which subsides in about two weeks. Healing occurs during the latter period. Another application may be made in five or six weeks from the beginning of the treatment if deemed desirable.

Solutions of Radium in Gelatine. At the annual session of the American Electro-Therapeutic session, held in New York City, September, 1909, Dr. Frauenthal presented a series of interesting cases of cancer treated by injections of radium in gelatine. A salt of radium bromide of a strength of twenty-five thousand uranies is dissolved in an ounce of gelatine, and a quarter or less of this solution injected into the tumor. Similarly bougies are coated with the same preparation and introduced into the rectum, vagina, or other inaccessible cavities.

Preparation of cocoanut charcoal saturated with the radium emanation, as recommended by Dr. Shober, Chapter XXIII, Part I, may also be used. These methods are also applicable to inoperable deep-seated cancer in any situation.

X-ray. The results of X-ray treatment in this disease have been found very satisfactory. A low tube should be used with an equivalent spark resistance of about three inches. The treatment may be continued until a well-marked erythema is produced, the surrounding parts being properly screened. The treatment should then be discontinued and the healing allowed to proceed. Circumstances must, however, determine the details of management in each case.

Concentrated Light Energy. This may be used rather as an adjuvant to the X-ray, though Morris reports seven cures in thirteen cases of rodent ulcer.

Eczema.— *X-ray.* This has been found to be of striking value in certain types of eczema, particularly in rebellious types of chronic eczema, like squamous eczema of the hands. In exudative types also it has proved very efficacious. It should not supersede careful regimen and hygiene, but should be welcomed as a most useful weapon with which to attack this disease. A single irradiation is sometimes sufficient to produce a marked result.

Light Energy. A large number of cures have been reported from exposure to light energy. The electric arc has seemed to act most favorably, though Minin reports a case successfully treated with his blue lamp. Better results have been secured in the electric arc bath than with the concentrated light of the electric arc. This would indicate that the systemic conditions underlying the disorder were favorably affected by the complete exposure of the body.

Furuncle or Boil.— This may be aborted by

the application of the direct current as already explained under the head of carbuncle.

X-ray. Exposure to the X-ray, as in acne, has been found of much value.

Herpes.— *Herpes simplex* may be aborted by the application of a mild direct current by means of a moistened electrode over the affected area.

Herpes Zoster. The severe neuralgic pains characterizing herpes zoster have been relieved by applying the moistened electrode over the course of the intercostal nerve.

Blue Light. This should be applied for its analgesic effect. The control which blue light has over superficial neuralgias is remarkable.

Icthyosis.— *X-ray.* This has been regarded as a most intractable disease. Yet Leduc has reported the case of a boy of twelve afflicted from infancy with this disease, who had tried every form of treatment without success, but was completely cured by four exposures to the X-ray.

Lentigo or Freckles.— These may be touched with a needle attached to the negative pole. A slight electrolytic effect is thus produced, sufficient to remove the pigment or destroy the pigment-producing layer of the epidermis. Care should be taken to avoid scarring. Local applications by means of a moistened electrode are useful.

High Frequency. The high frequency discharge from a fine metallic point by judicious employment will affect favorable results.

Lupus Erythematosus.— This is a most refractory disease. Morris and Doré, however, report

two cases cured by light treatment. Upon the whole the results obtained by the use of light energy have been rather more successful than those resulting from the use of the X-ray. There is with all of these methods, including high frequency applications, temporary improvement, but the ultimate results have been discouraging.

Lupus Vulgaris.— *Light Energy.* The results of Finsen's work are well understood. According to his technique the time necessary for a cure of lupus is from four and one half to six months. The cosmetic results of light treatment are excellent. Healing takes place without scar tissue.

X-ray. This form of energy rivals light in the brilliant results which follow its use. Its first effect seems to be more rapid than that produced by light. Its later action upon deep-seated nodules is slow. The X-ray seems to be more effective when the mucous membrane is involved than light, and when the nostrils are effected, the X-ray is used from necessity. The two methods may be combined where extensive surfaces are involved, the X-ray being used as a preliminary treatment.

High Frequency Applications. These applications have been found advantageous when administered (*a*) by the brush effleuve, owing to some extent to the large quantity of ultra violet rays which it contains; (*b*) by vacuum tube electrodes, and (*c*) by general electrization as supplied by the auto-condensation couch.

Naevus Lipomatodes.— In this type, in which there is fatty and connective tissue in the pigmented

area, the electro-cautery wire may be used with success, followed, if necessary, by electrolysis.

Naevus Pigmentosus or Pigmentary Mole.— If accompanied by hypertrophy of the skin, this may be removed by the method described under angioma, telangiectasis. If without hypertrophy, it may be destroyed by multiple punctures, as described under the head of angioma, naevus vasculosus.

High Frequency Discharges from a metallic point may also be used to advantage in the removal of pigmentary deposits. This method has the advantage of perfect control, and the operator soon learns by experience how long the discharge should be permitted to flow to accomplish the desired end.

Naevus Pilosus or Hairy Mole.— In this condition all that is needed in many cases is the removal of the hairs in order to destroy the pigmentary deposit. When this result has not been attained the mole may be removed by the methods already described.

Milium.— *Electrolysis.* These small, rounded, whitish masses containing sebaceous material are easily and successfully removed by electrolysis. The electric current effectually cauterizes the cavity and prevents recurrence of the disease.

Molluscum Contagiosum.— These tumors, much larger than the preceding, and containing a soft, whitish, greasy, and semi-solid substance, are readily removed and successfully treated by electrolysis.

Molluscum Fibrosum.— This disease, rare in this country, and characterized by hard, nodular, and circumscribed tumors composed of connective tissue

situated in the normal skin, may be removed, when deemed desirable, by means of the electro-cautery loop. This treatment is especially suited to the pedunculated variety, though it is applicable also to sessile fibromata. Where the growths are small they may be removed by electrolysis.

Morphea.— This is a form of scleroderma which is rare. Localized treatment with the direct current in conjunction with massage and drug medication is recommended by Hardaway.

Pruritus.— *X-ray.* The X-ray is found most useful in this neurosis, a few irradiations sufficing to relieve the annoying and sometimes intolerable itching and burning which accompany it.

High Frequency Effleuve. Only less serviceable, perhaps, is the high frequency effleuve, or glass vacuum electrode application.

Radium. Perhaps the most brilliant results in the treatment of this disease have been obtained by the use of radium.

Direct, induced, and static currents have all been used successfully in this disorder.

Psoriasis.— *X-ray.* This obstinate and rebellious disease yields, in many cases, to X-ray irradiations, more especially when combined with arc light treatment.

Arc Light. This should be administered on alternate days. The author combines the X-ray and arc light treatment with a strictly vegetable diet, believing that animal food is unfavorable to recovery and tends to relapses.

Figure 244 represents a young woman, age thirty,

afflicted with generalized psoriasis. Three months' treatment in a hospital by the use of drugs had aggravated her trouble. Daily treatments for a similar period at the author's office, with arc light and X-ray exposures occurring every other day, produced the condition as shown in Figure 245. Dr. Cleaves regards light energy as almost a specific in this disease.

PEMPHIGUS.— *Arc Light.* This disease is exceedingly refractory. Yet Dr. Max Heims reports two cases of chronic pemphigus cured by blue light from an arc lamp.

Fig. 244.

Fig. 245.

Ultra Violet Light. Similarly a case of pemphigus neonatorum is reported by Dr. Cleaves which yielded to the ultra violet light.

PURPURA.— *Induced Current.* Shand, of Glasgow, has reported a case in which the subcutaneous hemorrhages characteristic of this disease ceased after repeated applications of this current.

SARCOMA.— This frequently originates from the degeneration of a pigmentary naevus or mole. It is also secondary to sarcoma of other organs. The same treatment may be employed as is described under epithelioma.

SCROFULODERMA.— This term includes a number of diseases which are either tuberculous or syphilitic. The term " scrofula " was formerly applied to them.

The type with which we are most familiar in this country is *scrofuloderma ulcerosum* in which hard, painless, movable masses usually undergo softening with the eventual production of cold abscesses. Such conditions are markedly benefited by X-ray irradiations and the high frequency effleuve. Theoretically any light containing a high proportion of ultra violet rays applied by means of a compressor in order to secure anemia of the tissues should likewise be beneficial, for reasons explained in Chapter XXII, " Physiology of Light Energy."

Concentrated Energy of the Electric Light. The X-ray may be alternated with the arc light or followed by it.

SYPHILIS OF THE SKIN.— *Mercury Phoresis.* Where the diagnosis of syphilis has been made, the

initial lesion may be successfully treated by phoresis, a soluble mercurial salt being carried into the tissues by the electric current. This method is equally applicable to the papular, tubercular, and gummatous types of the secondary stage of syphilis. Constitutional treatment is, of course, not to be neglected. None the less, the speedy removal of a syphiloderm and the incidental and preliminary alteration of its characteristic color are a source of great satisfaction to the patient.

Tattoo Marks.— These may be speedily removed by electrolysis. The needle attached to the negative pole excites so much inflammation in the pigmented tissues that they throw off the foreign material deposited there.

Ulcers.— These may be stimulated by the application of an electro-cautery to the indurated edges and also to the surface. The direct current may be employed to carry zinc or copper ions into the ulcer. The effect is to stimulate the ulcer to the production of healthy granulations.

Light Treatment. Ulcers receive remarkable stimulation from exposure to light. Frequently islets of scar tissue appear in the center of ulcers within twenty-four hours after exposure to the blue light. This is in marked contrast with nature's method of repair when unassisted by light, since almost invariably in such cases scar tissue appears around the edges of the wound. With the assistance of light nature seems to be able to set up independent centers of healing and thus rapidly hasten cure. Thorough asepsis and rapid healing are secured

by the exposure of raw surfaces and wounds to the rays of the arc light. Superficial wounds are quickly sterilized by the ultra violet light. The arc light will rapidly produce a somewhat glazed film over the surface of a wound, beneath which, without other dressing, healing proceeds quickly and painlessly.

Warts.— These may be treated like naevi, as already described under that heading.

Phoresis. Ions of magnesium may be carried into these little growths by phoresis. A pad of lint or blotting paper may be saturated with a five per cent solution of magnesium sulphate, and the current introduced by means of a platinum or carbon electrode attached to the positive pole. The result is highly satisfactory.

Wounds.— The existence of small wounds upon the surface of the hand may be determined by immersing it in a basin of water containing one of the poles carrying a direct current. The location of the puncture or wound can be readily determined by a smarting and burning sensation at the point of injury.

Arc Light. Where the skin has been cut or abraded, rapid healing may be secured by exposure of the raw surface to the arc light. The wound is quickly glazed, and the process of repair greatly accelerated. No medicament is required.

Xanthoma. — This is a new growth of the skin and mucous membrane, which occurs in several varieties. *Xanthoma planum* appears by preference upon the eyelids, near the inner canthus,

gradually spreading over the lid and sometimes the cheek. *Xanthoma tuberosum* is a larger variety appearing over the flexures of the hands, feet, joints, and scalp. *Xanthoma diabeticorum* is a rare disease occurring in diabetics. In all these varieties *xanthoma* appears as yellow, yellowish-white, or yellowish-brown patches, imbedded in the skin or mucous membrane.

Electrolysis. They may readily be removed by the electric needle.

Electro-cautery. This is also a serviceable method of treatment.

X-ray. Willmott Evans, at a meeting of the Dermatological Society of London, Nov. 12, 1902, showed a case of xanthoma of the elbows successfully treated with the X-rays.

CHAPTER IX

DISEASES OF THE NERVOUS SYSTEM

I. Degenerations of the Cord.— Under this head we shall discuss *Locomotor Ataxia*, *Primary Lateral Sclerosis*, *Ataxic Paraplegia*, and *Progressive Muscular Atrophy*.

In these conditions the underlying pathological condition is a sclerosis. There is much evidence tending to show that electrical treatment produces beneficial results in these conditions. It is not assumed that there is regeneration of degraded cells, but that the stimulating effect of the electric current develops increased energy in the unimpaired cells, and thus tempts them to perform vicariously the functions of those that are damaged. Thus when a stimulating current is applied to a damaged muscle, the uninjured ganglionic cells take up the function of those that have been destroyed and through the reflex arc send a more energetic motor response to the area of stimulation. Nor must the electrical gymnastics in the damaged muscle produced by interrupted currents be forgotten, nor the influence upon centers of nutrition. A careful review of what has already been said in relation to the physiology of the direct current in Chapter III, Part I, will perhaps suggest

to the student additional explanations of the manner in which beneficial results are secured in this class of intractable disease.

Locomotor Ataxia.— *Direct Current.* A large pad moistened with salt solution attached to the negative pole should be applied to the spine and a similar pad to the extremities or to the sternum. The treatment should be administered daily and last ten minutes. For the purpose of influencing the sympathetic, the negative pad may be placed beneath the ear and the positive on the spine. An alternative treatment is

Electrization by the Bath. This is administered as already described in Chapter IX, Part I. It should continue ten or fifteen minutes, and be given every day for five or six days, and repeated after an interval of a week.

The Induced Current. This may be administered in conjunction with either of the above.

Static Electricity. Better results than the above are produced by the application of static electricity.

(*a*) *Wave Current.* Place a piece of block tin or soft metal twelve inches long by two or three broad along the spine, holding it in place by the pressure of the clothing, or a band of cloth tied around the body. Connect the patient with the positive pole, and continue treatment for twenty minutes. The purpose is to reduce congestion. The spark gap may be four or five inches in length.

(*b*) *Static Sparks.* To improve the condition of the uninjured cells and increase their vicarious ac-

tion, thick sparks should be administered to the spine.

(*c*) *Static Induced Current.* To restore sensation to anesthetic areas, particularly the feet, the static induced current should be employed.

Blue Light. To assist in reducing congestion and hyperemia, the light from the arc lamp filtered through a blue screen should be thrown upon the back.

X-ray. The X-ray applied to the spine has been found by Dr. Dawson Turner to be of some service.

Electric Arc Baths. Dr. Cleaves reports a case of marked improvement in tabes dorsalis from the use of arc baths. Here the addition of the lower frequencies to the chemical frequencies seems to have been a distinct advantage.

Phoresis. Dr. Dawson Turner lays ten layers of lint saturated with a weak solution of sodium chloride over the spine. Upon this is placed a metal electrode attached to the negative pole. The feet are immersed in a bath attached to the positive pole. A strong current is then passed for half an hour.

It is not assumed that all of these treatments can be employed each day. They should, however, be alternated, more especially the static and blue light treatment.

The Fraenkel exercises and mechanical vibration are to be employed when indicated, the former especially in the ataxic stages of the disease. These treatments should be administered daily. It is idle to expect in so chronic a disease, in which the organic

changes and the tendency toward progressive degeneration of central and peripheral cellular tissue are so marked, that radical improvement can be secured without long continued treatment. The patient should, therefore, be treated continuously for a year or more.

Primary Lateral Sclerosis. In locomotor ataxia the posterior columns of the spinal cord are affected. In this disease the lateral columns have become the seat of degenerative changes. Treatment by electricity and light as outlined above is applicable to primary lateral sclerosis, and has produced favorable results, according to Morton, arresting some cases and curing others.

Friedrich's and Hereditary Ataxia, which are somewhat infrequent diseases, may be treated in a similar manner.

Ataxic Paraplegia.— In this disease the seat of degeneration is in both the lateral and posterior columns. Assuming that the disease is wholly a degeneration, though of course it may have had a precedent inflammatory origin, it is proper to apply the treatment by light and electricity as outlined above.

Progressive Muscular Atrophy.— Here the seat of disease is no longer the white matter of the cord, but the ganglion cells of the anterior horns of the gray matter, though it may invade the pyramidal tracts, the motor roots, and the motor nerves. Moreover, the lower segment of the motor path is most frequently involved, that is, the path from the cells

of the anterior horn through the nerve trunk to the muscle. To this type must also belong progressive bulbar paralysis of the lips, tongue, palate, and throat due to atrophy of the nuclei of the nerves supplying these parts.

In the spinal cord diseases and in the differentiation between true and pseudo bulbar paralysis constant resort must be had to the responses of muscles to electrical stimulation, as described in Chapter X, Part I, on electrical testing.

In this disease, as in the preceding, the constant, induced, and static electrical treatments, together with the use of the blue light as already described, should be employed. Results in many cases have been favorable and encouraging.

II. Inflammatory and Degenerative Diseases of the Cord. Myelitis.— This may be acute or chronic.

In the acute type a previous softening of the cord occurs with thickening of the meninges and adhesions to adjacent tissues. It is probable that this stage has never been treated electrically. Morton would treat this condition by the application of a large negative pad to the affected area with as high a current strength as can be tolerated by the patient, and administer daily treatments lasting twenty minutes. The positive pole should be placed upon the sternum. It is to be observed that it is usual to employ the positive pole over the site of inflammatory action, and therefore that this rule would indicate the choice of the positive pole over the spine.

In the chronic condition one pole is to be placed above the affected area and the other below. Where, however, descending degenerations of the cord have taken place as evidenced by spastic rigidity and exaggerations of reflexes, the treatment should be administered the whole length of the cord. There should be frequent changes of polarity by means of the pole changer.

Induced Currents. These may be employed over the back and lower extremities.

Static Electricity. For the purpose of hastening absorption and restoring sensation static sparks should be applied to the spine. Where degeneration has been well established, it is scarcely to be hoped that anything more than a greater or less degree of improvement can be secured in the treatment of this unfortunate condition.

Acute Anterior Poliomyelitis (Infantile Paralysis).— There is no disease in which more important results can be secured by the use of electricity than in this, nor in which there is a greater unanimity of opinion as to the value and importance of making an early resort to this remedial agency. Four stage may be noted.

(1) The acute stage lasting several days.

(2) The stationary stage, lasting several days to six weeks.

(3) Stage of retrogression lasting six to twelve months.

(4) Chronic stage with remaining defects. It is entirely possible that the application of electric

currents to the spine during the stage of invasion might mitigate the severity of the exudative process, or cause a rapid absorption of exudates. It is customary, however, to delay treatment until the stationary stage has been reached, or sometimes to a later period. Here there is frequently neuritis, indicated by pain upon pressure and movement of the limbs. For this condition the mild direct current should be employed with the positive pad upon the painful areas and the negative upon an indifferent spot. Similarly the positive electrode may be employed at the same sitting over the affected areas of the spine. The location and amount of damage in the spinal cord may be determined by an electrical examination. The treatment above described is peculiarly applicable to the second and third stages of infantile paralysis, the positive pole applied to the focal disturbance in the spinal cord and the negative pole labile to the affected nerves and muscles in the extremities. The design is to hasten, if possible, regeneration of nerve and muscle fiber by the specific polar effect of the continuous current, rather than to over stimulate it by constant contractions. Even at this stage, however, it may be desirable to employ the interrupted direct and induced currents, especially where muscular atrophy is marked.

In the last stage induced or interrupted direct currents applied to the atrophied muscles are especially indicated. Even where electrical responses are not elicited at first, it frequently happens that the persistent use of interrupted currents will restore excitability and some degree of voluntary power.

Particularly in this stage the affected extremities should be treated every day by mechanical vibratory stimulation or massage. The nurse or mother may be taught how to rub the affected parts. Where orthopedic appliances are used, these should be removed each day, and the child taught by carefully prescribed exercises how to exercise the damaged muscles.

Electric Baths. Interrupted currents can very well be applied by means of the electric bath.

Static Sparks. These have been employed to produce muscular contraction when other means fail.

III. Diseases of the Peripheral Nerves.— The extent of injury to the nerve trunk should first be ascertained by electro-diagnosis. This will reveal (*a*) its power to conduct sensory and motor impulses; (*b*) its excitability to electrical stimuli, and (*c*) the condition of the muscles which it innervates.

Paralysis of the Ocular Muscles.— See Chapter V, Part II.

Neuralgia of the Trigeminus.— It is, of course, to be assumed that careful inquiry is to be made into the cause of this disease, and appropriate treatment directed to its removal, whether dental disorders, exposure, anemia, disease of the eye or nose, syphilis, gout, rheumatism, epilepsy, malaria, pressure, or trauma.

(*a*) *Symptomatic Form.*

Direct Current. The well-moistened pad attached to the positive pole should be applied to the point of emergence of the nerve from its bony sheath,

the negative pole being applied in the cervical region. The current strength may be from one to three milliamperes, and continued for five minutes several times daily. It usually affords relief. The anode should measure one and one half inches in diameter, the kathode four or five. Neuralgia affecting the occipital, cervical, bronchial, and intercostal nerves should be similarly treated.

Induced Current. Similarly the points of emergence or other sensitive areas may be treated with the induced current by means of the wire brush.

Blue Light. A most effective and satisfactory treatment is the blue light from a screened arc lamp thrown upon the painful areas for twenty minutes. A single brief treatment is sometimes sufficient to affect a cure.

High Frequency Vacuum Tube. Excellent results have been obtained from the use of currents of high frequency administered with a vacuum tube.

X-ray. This has proved very efficacious in some cases.

(*b*) *Tic Douloureux.* The cause of this type of trigeminal neuralgia presents much greater difficulty. The above treatments should be faithfully tried. The origin of the trouble may be due to the pressure of the inflamed nerve as it passes through some of its bony canals. Recognizing the obstinacy of this disease, Bordier recommends the direct current of large volume carrying from thirty to eighty milliamperes, continued for an hour. The aim is to produce nutritional changes in the affected nerve. In

order that currents of such magnitude may be carried without discomfort, the active electrode should measure twelve square inches and the indifferent electrode forty square inches. The same method may be employed here as above.

Facial Paralysis.— This may result from cerebral disease, cerebral tumor, or meningitis, but oftener from swelling of the nerve trunk as it passes along the Fallopian aqueduct. It may also be associated with disease of the ear, due to extension of the inflammatory process. In paralytic conditions treatment should be applied directly to the affected muscles and nerves by means of the *direct current*, and reflexly by stimulation of the sensory nerves by means of interrupted currents.

Direct Currents. Therefore, a moistened pad attached to the negative pole should be applied labile to the affected muscles and nerves, the indifferent pole upon the nucha or upper cervical spine. The treatment should be applied daily and continue for ten minutes. The current strength should be as large as the patient can endure without too much discomfort.

The Induced Current should be similarly administered by means of a wire brush to the affected areas and continued for ten minutes. These treatments may be administered in succession or upon alternate days.

Mechanical Vibration. The affected areas may be stimulated by mechanical vibration.

These treatments are applicable to all varieties of paralysis.

Anesthesia and Hyperesthesia of the Auditory Nerve.— Here the conditions requiring treatment are anesthesia and hyperesthesia, the former producing deafness, the latter tinnitus. According to Erb, Brenner, and De Watteville, the healthy auditory nerve acts only to anodal opening and kathodal closing excitations. The reaction consists in sounds that are variable as to pitch and duration, and may be of a hissing, humming, ringing, or buzzing character.

For *Nervous Tinnitus* that pole should be applied in front of the ear, covering the tragus, which is found to diminish the noises, and should be held there until they have disappeared. The current may be continued for ten minutes, and should be reduced to zero by imperceptible degrees.

For *Nervous Deafness* the direct current should be employed with slow interruptions by means of the pole changer.

The principles already announced are applicable to the treatment of paralysis of the brachial plexus, known as Erb's paralysis, or root paralysis; paralysis of the circumflex, musculo-spiral, musculo-cutaneous, ulnar, median, sciatic, anterior crural, peroneal, and tibial nerves, and it would seem scarcely necessary to repeat in each case the treatment which is applicable in all essential particulars to all these varieties of paralysis.

Static Sparks. It is desirable when the muscles fail to respond either to direct or induced currents to employ static sparks.

Wave Current. This may be applied to the affected areas for its nutritional effect.

Brush Discharge. Where there is pain or hyperesthesia the static brush discharge is useful, especially over the scalp.

Sciatica. In selecting the appropriate treatment for this condition the cause of the trouble must be patiently sought. There may be pressure within the pelvis, a prostatic condition, an anal fissure, hemorrhoids, or constipation. There may be an alteration in the relation of the sacrum and os innominatum at the sacro-iliac articulation, producing conditions simulating sciatica. Finally, it must be remembered that a true bursitis may exist at the point where the glutei muscles play over the great trochanter. Similarly a bursitis may occur at the point where the tendon of the psoas and iliacus plays over the supracapsular ligament. In all these cases the sciatic nerve may ultimately become involved. Such conditions must, of course, be corrected by appropriate treatment. Sciatica is a peri-neuritis of the sciatic nerve, and may be successfully treated by the

Direct Current. A large, well-moistened electrode having a surface of twenty-five square inches attached to the negative pole is placed beneath the sacrum, the patient being in the recumbent position. The indifferent pole is applied successively to tender spots along the course of the nerve. A current strength of ten to twenty milliamperes may be employed for five or ten minutes every day or on alternate days.

Induced Current. An induced current with very

rapid interruptions and high tension may be advantageously employed. This may be alternated with the direct current.

High Frequency Effleuve. The high frequency vacuum tube along the course of the affected nerve sometimes produces satisfactory results.

Static Wave Current. This is a most useful method of combating this painful affection. Over the painful area a flexible metal electrode is moulded and a treatment lasting twenty minutes administered. Until relief is secured treatments should be given daily. The current should not be strong enough to produce discomfort.

Static Sparks. In some instances pain is relieved sooner and more effectively by the use of sparks over the affected areas. These should be proportioned to the tolerance of the patient.

Arc Light. For deep penetration of the pelvic tissues the full spectrum should be employed and treatment continued sometimes for an hour. Where the painful areas are more superficial, as in the nerves distributed to the foot, the blue light from an arc lamp may be employed.

Where adhesions exist exploration of the nerve and detachment of adherent tissues may be necessary to a cure. Preceding resort to surgery, massage, or mechanical vibration is indicated in order to avoid, if possible, surgical interference. In the earlier stages of the trouble congestion is likely to be increased by motion, and rest should be enjoined.

Brachial Neuritis. The same principles are applicable to the treatment of this condition as have

already been elaborated in the management of sciatica. Care must be exercised to determine whether the neuritis is uncomplicated. In many instances what was formerly regarded as a simple brachial neuritis has been found to be a peri-arthritis of the shoulder, dependent upon inflammation of the subacromial bursa. In many of these cases examination will disclose adhesions about the joint, manifested not only by painful but by limited motion, particularly in abduction and rotation. In these cases it becomes necessary to take steps to detach these adhesions which limit motion, and, by involving the nerve, produce pains of a dragging and tearing character. Such a result may be gradually accomplished by exercises designed to stretch or detach the adherent tissues, or in some cases by resort to surgical procedure. In still other cases forcible stretching under ether successfully accomplishes this result. To assist in the softening and detachment of adhesions the

Direct Current is of assistance. A pad well moistened with solution of common salt is attached to the negative pole and placed over the shoulder, the hand being immersed in a pan of water, into which an electrode is placed, attached to the positive pole. A current of eight or ten milliamperes may be employed. Treatments should be given two or three times a week. Where no complication exists, and the problem is an uncomplicated neuritis, the treatment described under sciatica is applicable.

IV. Psychoses and Neuroses.— It is readily

admitted at the outset that it is difficult to determine the share which suggestion has in the undoubted improvement which follows in many of these cases from the employment of different forms of electrical treatment. That suggestion plays an important role in some cases is not to be doubted. We must not forget, however, that electricity produces real, not imaginary, effects, and that these effects can be readily demonstrated. These include phoresis, electrolysis, vasomotor, and reflex phenomena, and probably trophic effects upon nerves and tissues. These have been discussed elsewhere, and are here recapitulated in order to emphasize the fact that electricity produces physiological phenomena.

The physician should not hesitate to use electricity because of the possible association of suggestion with the treatment employed, nor because he cannot assign to each method the exact measure of its utility, nor, indeed, even if he regards suggestion as the predominant influence. It is impossible to dissociate the curative value of suggestion from any line of treatment. It is always operative wherever successful results are achieved. Nor should the increased effect due to impressive or spectacular apparatus be despised if only he thereby succeeds in benefiting his patient. All that we can hope in this respect is that continued observation and experiment will finally enable us to determine where the influence of the one ends and that of the other begins. In the mean time we shall do wisely to attempt to benefit patients afflicted by these troubles by such

positive means as are at our disposal, instead of adopting a *laissez-faire* policy of timidity and uncertainty.

Milder Psychoses. Of these Erb says, "They can in certain cases be favorably influenced, and sometimes cured by the electric current, even in cases in which all other possible remedies have long been tried in vain." These cases do not belong to the graver psychoses, but rather to border line conditions. These include mental stupor, torpor, melancholia in its milder types, and acute dementia, and are influenced most favorably when they are dependent on neurasthenic conditions, or such functional disorders as impaired nutrition, derangement of circulation, or morbid association of ideas.

Direct Current. This method has the high authority of Arndt, Lowenfeld, and Erb. Where depression and torpor exist it is recommended to place the kathode on the head and the anode at the nape of the neck; where irritation is present, to place the anode on the head and the kathode on the neck. Other authorities doubt whether the interpolar effects differ according to the position of the poles, and affirm that equally good results are secured by either position. It is well, however, to adopt a technique and adhere to it until better results are secured by making a permanent change.

Vertigo may be produced by currents carried through the brain. It is therefore important to use weak currents and to avoid breaking them. General electrization, as elsewhere explained (Chapter IX)

may be employed. The treatment should not last more than ten minutes, and should be given daily.

Static Electricity. This is especially useful in these cases. The crown breeze is easy of administration and often produces excellent results. For the purpose of allaying pain or suppressing paresthesia sparks serve a useful purpose. They are valuable also in depression and torpor.

Electric Baths. These may be employed as an alternative treatment.

Graver Psychoses.— The limits assigned to this work do not permit an exhaustive consideration of the electrical treatment of the graver psychoses. So unpromising has seemed the field to the alienist that for the most part little is now done in these cases, except to sequestrate the unfortunate victims of mental trouble and abandon them to the natural course of the disease. There are those, however, who have secured excellent results by the use of electricity. Arndt, who has given more attention to the application of electro-therapeutics to the treatment of the insane than any other writer, says, " Electricity if used carefully and perseveringly is an invaluable remedy in the hands of the alienist."

Melancholia. Direct Current. " In melancholia especially," says Arndt, " I have found electricity a valuable agent." His method is to apply the positive pole to the superior cervical ganglion on each side, the negative pole being moved slowly on the same side, over the eyebrow to the occiput. General electrization may also be employed.

Static Insulation. This method has been found to yield excellent results.

Mania. Erb says that electricity is contra-indicated in any condition of profound excitement. Riggs remarks that where there is marked psychical exaltation, approximating mania, but falling short of it, electricity is of value. Benedict reports the cure of a case of mania with delusions of grandeur by means of the head breeze.

Paranoia. The use of electricity in this disease has been without benefit.

Cerebral Anemia and Hyperemia.— Riggs has shown that the interrupted direct current increases the amount of blood in the head. This was demonstrated by an examination of the eye disc before and after treatment. Lowenfeld affirms that with the positive pole on the forehead and the negative at the neck there is a contraction of the arteries of the pia mater, and in like manner dilatation of the arteries if the position of the electrodes is reversed. While the correctness of this view has been denied by others, it is still customary to observe this rule in the treatment of these cases.

Hysteria.—The multiform symptoms which this disease produces afford an excellent opportunity for demonstrating the utility of electricity in reinforcing suggestive treatment. While the disease may originate in an exaggerated susceptibility to suggestion, or as W. H. H. Myers has characterized it, in a disorder of the hypnotic stratum, it is yet most difficult in many cases to introduce into the patient's mind the counter-

suggestion requisite to a cure. Here the efficacy of electricity, with the profound mental and physical impressions which it is capable of producing, becomes apparent. In this emphasis upon the psychical side of the malady we do not lose sight, at the same time, of the profound physical effects which electrical currents may produce, as in the relief of pain, paresthesia, anesthesia, paralysis, etc.

It is necessary, of course, to associate with electrical treatment the commanding influence which positive instruction, inflexible will, and a strong personality produce upon the mind of the patient in the cure of these cases.

The method of treating hysteria must depend upon the purpose which the physician has in view. Local manifestations must receive local treatment. In general, it may be said that static electricity accomplishes the best results. It may be administered by means of the breeze, sparks, wave current, induced current, or vacuum tube, according to the circumstances of the case. Light treatment may be made extremely serviceable in these cases.

Equally for the convulsions of hysteria, whether in the ordinary form or the form of hystero-epilepsy, static electricity, induced and direct currents have been successfully employed. At La Salpetrière static electricity has been used. Charcot recommends direct currents, and Didier prefers induced currents. The latter places one electrode on the spine and the other on the side, or one on the back and the other on the epigastrium.

V. Neurasthenia.— It is most important to determine in this condition what causes underlie the manifold symptoms presented, whether shock, worry, excessive use of stimulants, or narcotics, dietetic imprudences, sexual excesses, infections, auto-intoxication, or fatigue. It is very evident that the determination of the cause gives the key to the treatment, and it is not assumed that one method of treatment is adequate to the management of all of these cases. Many of them will tax the skill of the physician to the utmost, and the progressive student will be glad to avail himself of the great service which physical therapy is capable of rendering.

Individual symptoms, as for instance constipation, are to be corrected by methods described elsewhere. Nor must it be forgotten that suggestion plays an important part in the etiology of these cases and must find its appropriate treatment by a resort to counter-suggestion. The constant supervision which the employment of physical methods demands furnishes an excellent opportunity to impart those suggestions of returning health which contribute powerfully to the recovery of the patient.

Static Electricity. This method avoids the necessity of disrobing, and admirably serves, when continued with associated treatment, to improve the condition of the patient. The form of application used will depend upon the end sought, whether to relieve local congestion, in which the wave current should be employed, to induce sleep, when the head breeze is indicated, or to allay pain, in which case the vacuum tube or the wave current will be required.

The older methods, the *direct and induced currents* may be employed. Where the symptoms are cerebral, the direct current may be carried longitudinally or transversely through the head, as already described.

The *Static Induced Current* would seem to serve every purpose for which the induced current is employed, and with less inconvenience to the patient.

Auto-Condensation. The patient is placed upon the auto-condensation couch and a current of from two hundred and fifty to five hundred milliamperes administered for a period of twenty minutes. A reference to the physiological effect of high frequency currents, as contained in Chapter XVI, Part I, will furnish an explanation of how auto-condensation can exert a favorable effect upon the treatment of these cases.

Electric Baths. These unite the beneficial effect of the bath with the advantages of electric treatment.

Electric Light Baths. It is difficult to exaggerate the advantage to be derived from the exposure of the nude body daily to the influence of the sun's rays or the electric arc bath. The treatment may be continued for an hour or more.

Cerebral Hemorrhage and Softening.— In these unpromising conditions it is permissible to carry weak direct currents through the damaged areas with the hope of promoting absorption of the clot, or serous effusion, establishing collateral circulation, and overcoming edema and hyperemia. The treatment should not begin earlier than the third or fourth week after

the onset of the disease. The anode (Erb) is usually applied to the side of the lesion. Where partial cerebral anemia arises from cutting off the circulation, direct currents are considered useful.

Faradization of the injured muscles may be employed with advantage.

VI. Cerebral Paralysis.—The following paralyses may originate from cerebral lesions: hemiplegia, diplegia, paraplegia, progressive bulbar paralysis, paralysis of the muscles of mastication, facial paralysis, paralysis of the hypoglossal nerve, and ophthalmoplegia. The principles upon which treatment is given in these cases have already been explained. It should be directed first to the area of cerebral damage, next to the paralyzed muscles, with the hope, in the former, of promoting vasomotor and trophic changes, and, in the latter, of improving nutrition of the muscles and influencing the brain reflexly to aid in restoring conduction to the motor nerve tracts. This is a group of diseases in which electrical applications are of extreme value, and a more particular description of the management of these cases is not required if the student in each instance makes a correct diagnosis of the cerebral lesion and bears in mind the object to be obtained by treatment.

VII. Epilepsy.—*Direct Current.* Electricity does not seem to have had a very serious trial in this discouraging disease. Strumpel says, "Electricity is apparently beneficial in occasional instances, and may be tried in connection with other remedies." Erb was decidedly favorable to the treatment of

epilepsy by the constant current. He placed the anode first on one side of the forehead with the kathode to the nape of the neck, using a weak current for one minute, then in the middle of the forehead, the kathode being over the occiput.

Wave Current. Snow recommends the use of the wave current in children, placing a soft metal electrode, having an area of sixteen square inches, over the back or abdomen, and administering daily treatments lasting twenty minutes.

X-ray. Branth reports a case in which marked benefit followed a course of X-ray treatment.

VIII. Chorea.—Of this disease Strumpel says, "A feeble current of galvanism is applied to the head (in the region of the motor centers) or the spinal cord is galvanized."

Direct Current. This should be applied longitudinally to the cerebrum, with a current of two or three milliamperes for two or three minutes, also to the spine with a strength of ten milliamperes five to seven minutes.

Static Insulation and Spray. These methods have been successfully employed. Where the wave current is tolerated, the results are still more successful.

General Electrization and the Electric Baths have proved useful.

IX. Paralysis Agitans.— (*Parkinson's Disease.*) In regard to this disease Strumpel thinks that if electricity is of benefit the case must be recent. Riggs says that electricity may palliate the disease, but

usually no more. The best results have been secured by a combination of hyoscine hydrobromate (gr. $\frac{1}{100}$), two or three times a day, and electricity. The treatment is longitudinal and transverse galvanization of the cerebrum, and galvanization of the sympathetic. Static electricity in the form of insulation and sparks may be employed. It is believed that the symptoms, more especially the tremors, are ameliorated in this rebellious disease, while the essential condition underlying it is not altered by treatment.

X. Hemicrania.— (*Sick Headache.*) We note two general types, one characterized by vascular contraction, pale face, somewhat protruding eyes, dilated pupils, prominent temporal arteries, the other by vascular dilatation, red, hot, and swollen face, contracted pupils, strongly beating temporal arteries. Occasionally these varieties are combined. The former may be called the anemic, the latter the hyperemic type.

For the relief of hemicrania different methods of application have been recommended. Jones says that in most attacks the headache may be relieved by applications of the current longitudinally to the head.

Bartholow has found relief in hyperemic attacks by a mild induced current confined to the skin of the painful region, and a stronger current applied to the cervical and dorsal spine. Others have obtained no benefit from treatments during the attack, but have found electricity an efficient agent in combating the disease itself. Thus Riggs uses static electricity in

both varieties. The static spray is directed to the painful area and also to the origin of the cervical sympathetic. This is combined with longitudinal, central, or subaural galvanization.

The Wave Current may be employed both during the attack and the interval between attacks, for the purpose of equalizing the circulation and improving the general nutrition. A long electrode may be applied to the vertebral column or an electrode having an area of from sixteen to twenty-four inches may be applied to the abdominal or lumbar region. The treatments should be administered daily or alternately.

XI. Insomnia.—*The Electric Bath* has a strong tendency toward the induction of somnolence.

Head Breeze. A tendency to sleep is often observed during the administration of the negative head breeze.

The Wave Current. In its tendency toward the reduction of arterial tension and the lessening of nervous irritability and the relief of nervous tension the wave current tends to cure insomnia.

Condensation Couch. High frequency currents with currents varying from two hundred to seven hundred milliamperes act in a similar manner.

XII. In Cerebral Sclerosis, Periencephalitis, Hydrocephalus, Chronic Menigeal Affections, and Athetosis, electric treatment ought to be employed, since in the first place these affections do not respond to drug treatment, and in the second place unexpected symptomatic improvement sometimes occurs.

The direct current is applied longitudinally and obliquely to the brain. The electrodes may also be placed below the ears and over the cervical cord.

XIII. Cerebral Syphilis.— *Direct Current.* Althaus believes that the direct current is useful in controlling the headaches, insomnia, and paresthesia characteristic of this condition.

XIV. Syringo Myelia. *X-ray.* M. Marinesco, of Bucharest, has reported two cases in which the results of X-ray treatment were " satisfactory for the tremors which have completely disappeared, as well as for the motor troubles."

Direct Current. The anode should be placed on the vertebræ and the kathode near the sternum over the affected nerves, and especially over a tender spot should it be found. This frequently gives prompt and final relief.

Induced Currents. The brush may likewise be used over the affected area.

Wave Current. A metal electrode should be applied to the affected area and the current administered for twenty minutes daily, until relief is obtained.

CHAPTER X

ACUTE ARTICULAR RHEUMATISM, ARTHRITIS, AND MISCELLANEOUS DISEASES

Table of Arthritic Diseases

- Arthritis
  - Infectious
    - Acute articular rheumatism
    - Gonorrhea
    - Tuberculosis
    - Other pyogenic infections
  - Non-Infectious
    - Gout
    - Arthritis deformans
      - (1) Atrophic
      - (2) Hypertrophic
      - (3) Villous

The subject of arthritis is of such importance that it is deemed desirable to present the above classification of joint diseases. It will be noticed that the ancient term rheumatism occurs but once, and that only as applied to the acute polyarthritis characterized by fever, pain, acid sweats, and a marked tendency to relapse and involve the heart. Chronic rheumatism does not appear, as it is probable that, where it follows an attack of acute articular rheumatism, it is a manifestation of a distinct pathological process. The tendency is undoubtedly toward a disuse of the term. The terms rheumatoid arthritis and muscular rheumatism have also been avoided, because they tend to perpetuate an unsound etiology and pathology.

The importance of joint disease and its peculiar

susceptibility to relief by physical methods make it incumbent upon the physical therapeutist to give careful attention to the etiology, pathology, and diagnosis of this disorder. The limits of this work forbid entrance into this inviting field, and we must. therefore, direct our attention to treatment.

Acute Articular Rheumatism.— The general conviction at the present time is that this disease is of microbic origin. It is customary to rely upon drugs in the management of these cases. There are those, however, who have secured good results from electrical applications. Lewandowski recommends the faradic brush. Jones concedes some value, but says, "There is no great scope for the employment of electricity in that condition."

Gout.— This is a disease of metabolism and should be managed very largely by control of diet and adjustment of exercise. It is not a common disorder, however, and is frequently confounded with other types of joint trouble. The following methods are found, in conjunction with proper dietary and hygienic regulation, to be of value.

Phoresis. Lithium carbonate, lithium chloride, and common salt have favorably affected the diseased process. Bordier reports a case in which there were large uratic concretions in both hands and elbows. Arm baths containing two per cent of lithium chloride were used, the circuit being completed by two large kathodal pads applied to the body. The treatments were given daily. The swellings diminished notably, and the tophi in the

knuckles became softened. Eighty to one hundred milliamperes were well borne, the treatment continuing for a month.

Direct Current. This is valuable even without medication.

Electric Baths with Direct or Sinusoidal Currents. These affect nutrition in a favorable manner.

Static Electricity. The wave current, the brush discharge, and sparks where they can be borne are useful because of their marked influence upon altered metabolism.

High Frequency Discharges. These are reported to have produced favorable effects.

Incandescent Baths. These will be found to be of great value not only for the relief of pain, but also for the elimination of toxic materials and the restoration of normal metabolism.

Gonorrheal Arthritis.— The indication is first to cure the gonorrhea. (See Chapter II, Part II, on Diseases of the Genito-Urinary System.) This intense pain must be relieved by fixation, or morphine if necessary.

Hot Air Baths. These are useful in the acute stage for relief of pain and production of hyperemia.

Incandescent Baths. These serve a similar purpose and probably more efficiently.

Tubercular Arthritis.— The physical methods applicable to the treatment of this disease are the X-ray and the arc light, as already described in Chapter VI, Part II, in the treatment of pulmonary tuberculosis.

The X-ray. This procedure is useful because of its tendency to increase the phagocytic power of the leucocytes, as indicated by the opsonic index.

The Arc Light. This is beneficial, also, because it tends to inhibit the growth of the bacillus through its effect upon nutrient media, and the increased supply of oxygen which it brings to the diseased area and which is fatal to the continued existence of anaërobic bacteria. The X-ray and the arc light may be alternated, the former being used one day, and the latter the next. The danger of X-ray dermatitis may be avoided by combination of these methods.

Other Pyogenic Infections.— Acute diseases like measles and pneumonia may result in joint infections.

The Arc Light. This is useful because of the hyperemia which it produces, and the consequent increase of leucocytes which are carried to the battlefield to resist the invasion of the pus-producing germs.

X-ray. This may be used in alternation with light, though the latter may be sufficient without such aid to restore the joint to its normal condition.

Non-Infectious Types. In the non-infectious types of joint disease we have a collection of rebellious conditions which refuse to respond to any variety of drug treatment. They offer a field for the enthusiastic endeavor of the physical therapist, because by his methods only have any marked results been attained in the relief of these discouraging conditions.

According to the observation of the author, while differentiation into the different types, atrophic,

hypertrophic, and villous, is interesting pathologically, it does not as yet furnish the basis for any marked difference in treatment, so far as physical measures are concerned, though more extended study and observation may modify this judgment. Constitutional measures are undoubtedly indicated. The French are much impressed with the influence which auto-condensation and auto-conduction have in arthritic diseases, and there is, indeed, a general agreement that the high tension currents are useful in these cases.

Auto-Condensation. This should, therefore, be used both generally and locally. In its local application a sponge saturated with water or solution of common salt is placed on each side of the affected joint and a treatment lasting twenty minutes given. The amperage will depend upon the tolerance of the patient. The treatment should be administered daily.

Phoresis. The following method has been found exceedingly useful in these varieties of joint trouble. The negative pole is moistened with a saturated solution of iodide of potassium and the positive pole with a saturated solution of lithium chloride. Finzi has reported remarkable results from the employment of this method.

Incandescent Baths. These serve a useful purpose in some cases.

The Arc Light. This, however, is to be preferred, since it not only furnishes heat in sufficient quantities, but adds the much needed chemical frequencies in large proportion.

Hot Air. The superheated air of the oven has produced favorable results in some cases.

Static Sparks. The benefit derived from this treatment is unquestionable. It is a treatment, however, which all patients will not tolerate.

Static Wave Current. The profound vibration produced by this method secures excellent results in some cases. It is administered by applying soft metal electrodes about the affected joints and continuing the treatment for twenty minutes daily.

Induced and Static Induced Currents. These are useful in relieving pain.

Vacuum Electrodes. These serve to relieve pain, and also tend, like auto-condensation and auto-conduction, to affect the underlying dyscrasia. In the judgment of the author, the treatments which are most useful in the non-infectious arthritides are high frequency, light, and phoresis. It is highly probable that a more careful employment of phoresis will yet yield results of great value.

MYALGIA.— *Incandescent and Arc Light Baths.* These give great relief and frequently cure with a single exposure.

Static Wave Current and Sparks. Light treatment may be supplemented, if thought desirable, by static administrations.

High Frequency Vacuum Electrodes. These may be employed as a substitute for static administrations.

TORTICOLLIS.— The treatments applicable to myalgia should be employed here.

Bursitis.— The importance of this disease has only lately been appreciated. It is still another disease taken out of the general designation, rheumatism, and assigned to its proper place. The bursa which is oftenest affected is the one which lies under the acromion, and which has been called subacromial and subdeltoid. The inflammation of this bursa frequently extends to contiguous structures, and involves nerves and tendons, producing neuritis and setting up adhesions. Bursæ a reinflamed in other locations and frequently require treatment.

The pain in subacromial bursitis is of a peculiarly distressing character and the physician who can relieve it without operation will earn the sincere gratitude of his patient. The first indication is the relief of pain. This may be secured, in some instances, by fixation; yet fixation is not desirable if it can be avoided, since it tends toward impairment of motion through the development of adhesions. It is better, therefore, to permit a certain amount of motion and endeavor to control pain by physical treatments. Of these the most efficient is the

Concentrated Arc Light, directed to the whole area of pain and impaired motion, but particularly to the region of the affected bursa. Frequently the blue light will relieve pain better than the unscreened spectrum. This is true, particularly in those cases where neuritis is a marked feature in the clinical picture.

Static Wave Current. This is an admirable treatment. The flexible electrode should be moulded and applied to the acromial region and the sliding

rods separated three or more inches. The treatment should continue twenty minutes.

High Frequency Currents. These may serve a useful purpose when applied to the area by means of vacuum electrodes.

Mechanical Vibratory Stimulation. When adhesions have resulted from the organization of a plastic exudation, the vibrator is useful. The treatment should be conjoined with passive motion, in which an effort is made to stretch or finally separate the adherent structures. Later the patient is instructed to practice active exercises in rotation and abduction. A useful exercise is to place the hand behind the back and gradually lift it until it is carried as high as the seventh cervical vertebra. As the pain gradually subsides these motions become more easy of performance.

The physician may feel sure that patience and persistence will bring success in the management of this painful affection.

Flat Foot.— No affection has been more unintelligently managed than this. Originating almost invariably in bad shoeing, it requires for its correction that rational shoes shall be substituted for the irrational and arch-destroying shoes of commerce. The tendency toward pronation which the machine-made shoe encourages must be corrected. This can usually be accomplished, where the damage has not been too great, by supplying a shoe which tends to adduct and invert the foot. This is accomplished by placing a piece of rubber upon the outside of the heel. The

inflexible shoe support should be removed from the shank so as to permit freedom of motion between sole and heel. The inner line of the shoe should be straight, so as to favor the separation of the great toe from its fellows, which tends to give strength and power to the whole foot. It is needless to say that the shoe should not restrain the foot at any point, but permit it to adjust itself continually to the shifting lines of weight of the body. Where this is prevented the whole structure of the foot alters in order to adjust itself to an unnatural condition. All arch plates are vicious and harmful, since they undertake to give an unnatural support to a structure that needs no support, if it is permitted to shift itself without hindrance under the shifting weight of the body. In extreme cases the foot may be strapped for a few days in a position of adduction and inversion, in order to encourage it to assume the proper position. When this has been accomplished the straps may be removed. During these early days of treatment for the relief of pain, swelling, heat, and enlargement of the veins, the

Static Wave Current applied by means of a flexible electrode will be found of assistance.

Mechanical Vibratory Stimulation. The vibrator should be applied to the weakened and overstretched muscles and ligaments, particularly the tibialis anticus.

Erythromelalgia.— This affection, together with angina cruris, Raynaud's disease, and Morvan's disease, depends in some measure upon the presence

of an obliterating endarteritis. Frequently in erythromelalgia there is an associated lesion of the central nervous system, of which the peripheral symptoms are the result. The treatment of this disease is by no means encouraging, yet there can be no question that physical therapy affords the only hope of mitigating or curing it. Occasionally, of course, resort must be made to surgery to remove an area of gangrene.

The indication is to improve the circulation of the affected part. There is a true hunger for blood, of which the free access to the part is prevented either by vaso-motor contraction or by a pathological reduction of the lumen of the supplying arteries. For this purpose, when it can be borne, *vibratory massage* seems well suited.

Ordinarily any treatment which seems to raise the temperature of the affected part produces discomfort and seems to aggravate the condition. Cold applications allay pain and increase comfort. Elevation of the part and rest are indicated. A characteristic of erythromelalgia is its tendency to disappear spontaneously. Relapses are, however, inevitable. Under these circumstances it is quite possible to attribute a sudden cessation of pain and symptomatic cure to the procedures employed by the physician, which of course may have had their share in bringing needed relief. And it is no less incumbent upon the physical therapist to continue his remedial efforts, even if he is not able to assign to them their exact share in securing a welcome relief

from suffering. For in no disorder are the help and encouragement of the physician more needed. The intolerable pain and suffering occasioned by this condition call imperatively for the support of a cheerful and hopeful adviser, whose ingenuity will be taxed to the utmost to maintain the courage of the patient in the presence of frequent failure to relieve pain.

Obesity.— This occurs in three forms, *viz.* the plethoric, the anemic, and the hydremic. Both the plethoric and the anemic may pass into the hydremic form. In whatever form, however, this disease occurs there is suboxidation and imperfect elimination. For treatment the most efficient remedy is *the incandescent light bath.* This produces active sudation and large increase of heat. Weight is decreased both by the loss of fluid from the tissues and the oxidation of fat resulting from the increase of heat. That there is a marked metabolic stimulation is readily shown from the increase of carbon dioxide in respiration. Baths may be administered at first daily and then at intervals of one or more days. The temperature of the bath should not exceed 150° F. and may of course be made less according to circumstances. The exposure may last from fifteen to thirty minutes. This treatment may be succeeded by a shower bath, followed by *mechanical vibration, massage,* or *static insulation.*

Direct Current. Bordier employs large electrodes applied to the thighs, abdomen, and lumbar region, with currents running as high as 150 milliamperes. Treatments may last for thirty minutes.

Sinusoidal Currents. Excellent results have been reported by F. Allard in the use of sinusoidal currents.

Auto-Condensation. Several authorities have reported successes with application of auto-condensation and auto-conduction currents. Williams regards these results as due to improvement in digestion and increase in elimination of urates and phosphates.

ANEMIA AND CHLOROSIS.— *The Arc Light.* For most cases of anemia or chlorosis the arc light bath, because of its high chemical power and its effect upon the blood stream, should be employed. Winternitz observed in anemic patients an increase of the erythrocytes and hemoglobin after each bath. Where this disorder is associated with obesity, the *incandescent light bath* is preferred, because of its ability to produce active sweating and increased oxidation of the tissues. A shower bath or tepid douche may follow light exposure.

General Electrization. As an alternative treatment, though less effective, the electric bath produces excellent results.

Wave Current and Static Sparks. For their effect upon general metabolism the wave current may be employed. For local effect upon the pelvic organs sparks may be directed to the lumbar region.

CONVALESCENCE.— *Electric Bath.* Jones regards general electrization of much value in delayed convalescence.

Arc Bath. This treatment is admirably adapted to hasten convalescence from wasting fevers.

Rickets.— *Electric Bath.* Several cases have been reported as cured by general electrization.

Tuberculous Glands.— *The X-Ray.* These respond very favorably to X-ray treatment. This may be followed by exposure to the arc light with X-ray treatment on the intervening days.

Tuberculous Joints. — *The X-ray.* Good results have been reported from the use of the X-ray in tuberculous joints. The method is certainly deserving of trial and may be associated with the injection of tuberculin.

Arc Light. This should be used in conjunction with the X-ray as described above.

Sarcoma.— *The X-ray.* The occasional successes following the use of the X-ray in sarcoma justify its employment in inoperable or recurrent cases. The partial removal of a recurrent sarcoma tends sometimes to increase enormously the malignancy of the growth. It is, therefore, better to resort to the X-ray or, in very early cases, where the growth is small, to use radium. The successes of the latter under the circumstances just named have been remarkable.

Carcinoma.— *Zinc-Mercury Phoresis.* Reference has already been made to Dr. Massey's method of destruction of cancer by means of the introduction of zinc-mercury ions into the neoplasm. The operation is conducted under anesthesia and has secured results of the highest importance. The diffusion of the ions of mercury and zinc into the tissues accomplishes the result of destroying the neoplastic cells

by a certain selective action of the current upon the carcinomatous tissue. This is in marked contrast with the surgeon's knife, which cannot with certainty distinguish between healthy and unhealthy tissues. Moreover, this method is applicable to cases where surgery is impracticable, and deserves the serious attention of surgeons as an available weapon in controlling this formidable disease.

KEATING–HART'S FULGURATION METHOD.— This is a less effective method of attaining the destruction of cancerous tissue than that described above. The spark from a high frequency electrode is thrown into the raw wound after the surgical removal of the neoplasm.

X-ray. Except in superficial growths, as already described, or in inoperable cases, the X-ray should not be employed. After operation, however, all cases should be subjected to irradiation, in order to avoid the possibility of recurrence. This should be a routine procedure.

Radium. The use of radium should be confined to small superficial growths, or to areas which are not readily reached by surgical procedures.

Electrolysis. This method has been used with some degree of success.

VOMITING OF PREGNANCY.— *Direct Current.* Where this reaches the stage of hyperemesis, it has been controlled by the application of the positive pole above the clavicle between the attachments of the sterno-cleido mastoid, the negative being placed upon the epigastrium.

EXOPHTHALMIC GOITRE.— *Direct Current.* The

electrode should be placed on the inner border of the sterno-cleido-mastoid. Strumpel says, "the slowing of the pulse which sometimes comes on at once (vagus irritations) is striking." Vigoroux favors the induced current applied directly to the thyroid gland.

Wave Current. Here the treatment is both local and constitutional. For the former a metal electrode is applied directly to the thyroid gland, and continued daily at first for a period of ten minutes. For the latter, a similar but somewhat larger electrode is applied to the epigastrium, the whole treatment lasting about twenty minutes. The success of this treatment has been very marked, the tachycardia subsiding, the thyroid gland decreasing in size, the tremors disappearing, and the further progress of the disease stayed.

X-ray. Many cures have been reported from exposure to the X-ray. This induces lowering of the pulse rate, cessation of tremors, relief of exophthalmus and reduction in the size of the thyroid gland.

Induced Current. Masucci (*Rev. de Therapeut.* 1er *Oct.* 1908) reports a case of exophthalmic goitre much improved by the use of induced currents.

Electrolysis. This method has been employed and warmly recommended by Dr. G. Vaudey, of Marseilles. The steel needles attached to the positive pole are insulated by a layer of shellac, where they are surrounded by skin, and penetrate the gland to about the distance of one fifth of an inch.

Simple Goitre.— For convenience the treatment of simple goitre may be introduced at this point.

Wave Current. The wave current is employed by means of a metal electrode applied directly to the thyroid gland. This should be administered daily at first, and then at longer intervals. If the disease is attacked early, before hyperplasia has begun, a few administrations will cure it.

Phoresis. Attach negative pole to a pad moistened with a saturated solution of iodide of potassium. Apply to growth on one side, a moistened pad attached to the positive pole being applied to the opposite side. The treatment may last for twenty minutes with a current strength of from five to ten milliamperes. Mild sparks may sometimes be required.

Light. The arc light is most efficient in many of these cases. At times the use of the blue light produces very prompt and satisfactory results.

Saccular Aneurism.— *Direct Current.* Here the object is to obliterate the sac early by the production of a coagulum which subsequently organizes and leads to contraction of the walls of the aneurism. This has been successfully accomplished in numerous cases by the introduction of a coil of gold, silver, or platinum wire attached to the positive pole of the direct current battery. The length of wire may vary with the size of the aneurism, running from a few feet to a hundred or more, and the current strength from a few milliamperes to seventy or more. The sessions may continue for a half hour or more.

CHAPTER XI

SUMMARY OF TREATMENT

Most of the diseases whose treatment is briefly stated below have been discussed in the body of this work. Diseases which are better treated by other methods or for which physical treatment affords little promise of relief are not included. Intractable diseases in which all other methods have failed are frequently considered. Those in which electricity or other physical methods may be regarded as an alternative treatment are also briefly noted.

Acne.— (See page 410.) Arc light on intervening days. High frequency vacuum discharges. Ultra violet light.

Acne Rosacea.— (See page 411.) Electrolysis. Concentrated arc light. Direct current.

Adhesions, Pelvic.— (See page 337.) Wave current with rectal or abdominal electrode, direct current with ball electrode (*Fig.* 230) in vagina, with moistened pad on abdomen 25 to 30 milliamperes, thrice weekly.

After Pains.—Secondary induced current with moistened pads upon abdomen and lumbar region, five to ten minutes.

Alopecia.—(See page 411.) Crown breeze. Direct current. Concentrated energy of the electric arc

ALOPECIA AREATA.— (See page 412.) High frequency vacuum electrodes. Cupric phoresis. Ultra violet light.

AMENORRHEA.—(See page 311.) Direct current. Electric bath. Induced current.

ANEMIA.—(See page 469.) Arc light bath. Incandescent light bath. Electric bath. Wave current and static sparks.

Cerebral. (See page 449.)

ANGINA CRURIS.— (See Erythromelalgia.)

ANGINA PECTORIS.— (See page 388.) Direct current.

ANEURISM.— (See page 373.) Direct current.

ANGIOMA.— (See page 413.) *Naevus vasculosus or birthmark.* Direct current, tattooing with fine needle. High frequency spark. X-ray. Radium.

Telangiectatic. Same as above.

Cavernosa. Electro-cautery or electrolysis.

Of the Eye or Orbit.— (See page 381.)

APHONIA.— (See page 374.) Induced current. High frequency vacuum electrodes.

ARTERIO-SCLEROSIS.— (See page 389.) Auto-condensation. High frequency vacuum electrodes.

ARTHRITIS. — (See page 460.) *Gonorrheal.* Cure gonorrhea. Hot air baths. Incandescent baths.

Tubercular. X-ray. Concentrated arc light. (See also page 470.)

Due to other infections. X-ray and concentrated arc light.

Hypertrophic. (Osteo-arthritis.) Auto-condensation, general or local. Incandescent baths.

Concentrated arc light. Hot air. Static sparks. Static wave current. Induced current. Vacuum electrodes. Phoresis.

Atrophic. Same as above.

Villous. Same as above.

ASPHYXIA.— (See page 386.) Induced current. Direct current.

ASTHMA.—*Idiopathic.* (See page 386.)

Paroxysm. Induced current. Direct current. Wave current. Auto-condensation. Arc light and incandescent baths.

Interval. Same as above.

ATROPHY OF THE OPTIC NERVE.— (See Papillitis.)

BALDNESS.— (See Alopecia.)

BRONCHITIS.— (See page 390.) Electric arc baths. Concentrated arc light. Blue light. High frequency vacuum electrodes.

BRONCHIECTASIS.— (See page 390.) High frequency currents. The above treatments may also be used.

BURSITIS SUBACROMIALIS.— (See page 464.) Concentrated arc light. Static wave current. Mechanical vibration.

CARCINOMA.—*Mammary.* (See pages 344, 470.) Massey's zinc-mercury phoresis. Keating-Hart's fulguration in selected or inoperable cases. X-ray after operation.

Uterine. Same as above. (See page 344.)

Gastric and Intestinal. X-ray. (See page 399.)

Epithelial. Electrolysis. Electro-cautery. (See page 420.) Radium.

CARBUNCLE.— (See page 416.) Direct current, in early stage. Cupric phoresis. Electro-cautery.

CARUNCLE URETHRAL.— (See page 331.) Hot wire snare. Electrolysis. Cupric-phoresis.

CHALAZION.— *Meibomian cyst.* (See page 377.) Electrolysis.

CHANCROID.—Cupric phoresis.

CHANCRE.— Same as above.

CHILBLAINS.— Cupric phoresis. Moisten part with salt water and apply flat copper electrode attached to positive pole to lesions. Moistened pad upon adjacent surface. Five milliamperes every other day.

CHLOASMA.— *So-called "liver spots."* Direct current, negative pole attached to moistened pad over pigmented area. Frequent applications, 5 to 10 or more milliamperes.

CIRRHOSIS OF LIVER.—(See page 404.) Induced current. Arc light bath.

CHOREA.— (See page 454.) Direct current. Static insulation. Wave current. Electric bath.

CICATRIX.—(See page 417.) *Atrophic.* Direct current.

Telangiectatic. See Angioma.

Hypertrophic. See Angioma.

COLITIS.— *Mucous.* (See page 409.) Electric bath. Induced current.

CONSTIPATION.—(See page 391.) Direct current. Static wave current. Static induced current. Mechanical vibration. Sinusoidal current.

CONVALESCENCE.— (See page 469.) Electric

bath. Arc light bath. Static insulation. Static breeze.

DEAFNESS.— *Nervous.* (See page 442.) Direct current with slow interruptions.

DIABETES MELLITUS.—(See page 404.) Auto-condensation. Static wave current. Direct and induced currents. Electric arc bath. Mechanical vibration.

DIARRHEA.— *Chronic.* (See page 401.) See Enteritis.

DILATATION OF ESOPHAGUS.— (See page 396.) Direct current.

Of Stomach. Direct current. Induced current. (See page 400.)

DYSPEPSIA.— *Nervous.* (See page 397.) Arc light baths. Direct current. Induced current.

DYSMENORRHEA.— (See page 333.) *Infantile uterus.* Direct and induced currents.

Atresia or Stenosis. Direct Current. (See page 335.)

Membranous. Direct current. (See page 336.)

Congestive. Static wave current. (See page 336.)

ECZEMA.— (See page 422.) X-ray. Concentrated arc light bath.

EKTROPION.— (See page 382.) Electro-cautery.

ENDOMETRITIS.— (See page 338.) *Corporeal.* Cupric-phoresis.

Cervical. (Leucorrhea.) (See page 339.)

ENTERITIS.—*Chronic diarrhea.* (See page 401.) Induced current. Concentrated arc light.

ENTEROPTOSIS.— (See Gastroptosis.)

ENTROPION.— (See page 382.)

EPIDIDYMITIS.— (See Orchitis.)

EPILEPSY.— (See page 453.) Direct current. Wave current. X-ray.

EPISTAXIS.— (See page 370.) Cupric phoresis.

EPITHELIOMA.— (See page 420.) Electro-cautery, or electric needle. Zinc phoresis. Radium. X-ray. Light energy.

ETHMOIDITIS. NECROSING. (See page 372.) Zinc phoresis.

ERYTHROMELALGIA.—(See page 466.) Vibratory massage. Direct current. Phoresis.

EROSIONS OF THE OS.—(See page 342.) Cupric phoresis.

FEVER, HAY.— (See Rhinitis Hyperesthetic.)

FIBROIDS.— (See page 343.) Direct current. Cupric phoresis.

FIBROMA MOLLUSCUM.—(See page 425.) Electro-cautery.

FISSURE IN ANO.— (See page 365.) Cupric phoresis.

Of Nipples. Same as above.

Fistula. (See page 362.)

FLAT FOOT.— (See page 465.) Proper shoeing. Rejection of plates. Static wave current. Mechanical vibration.

FRECKLES.— (See Lentigo.)

FURUNCLE.—*Boil.* (See page 422.) Direct current. X-ray.

GALACTORRHEA.— Direct current, applied by means of a large moistened pad made especially for

the occasion. The nipple is not covered. Attach to positive pole.

Gastralgia.— (See page 397.) Direct current.

Gastritis, Chronic.—(See page 398.) Direct current. High frequency vacuum electrode.

Gastroptosis.—(See page 402.) General vibratory stimulation. Sinusoidal current. Arc light baths.

Goitre.— *Simple.* (See page 472.) Wave currents. Phoresis. Electrolysis.

Exophthalmic. Direct current. Wave current. (See page 471.) X-ray. Induced current. Electrolysis.

Glands.— *Tubercular.* (See page 470.) X-ray. Concentrated arc light.

Gonorrhea.— *Acute.* (See page 349.) Silver phoresis.

Chronic. Same as above. (See page 349.)

Gout.— (See page 459.) Phoresis. Static electricity. High frequency discharges. Incandescent baths. Electric baths.

Hemorrhoids.— (See page 358.)

Hemorrhage.— *Cerebral.* (See Paralysis.) (See page 452.) Direct current. Induced current.

Post Partum. Induced current. Introduce a uterine sound into uterus under strict aseptic precautions and attach to induction coil with rapid vibrations. The indifferent pole is attached to moistened pad upon abdomen. Uterus immediately contracts.

Nasal. (See page 370.)

Hemicrania.— *Sick headache.* (See page 455.) Direct current. Static spray. Static wave current.

HEPATITIS.—*Biliousness.* (See page 401.) Incandescent bath.

HERPES.—*Simplex.* (See page 377, 423.) Direct current.

Zoster. (See page 377, 423.) Direct current.

HEMIPLEGIA.— (See Paralysis, facial.)

HICCOUGH.— (See page 388.) Direct current.

HYPEREMIA.—*Cerebral.* (See page 449.) Direct current.

HYPERTRICHOSIS.—*Superfluous hair.* (See page 417.) Electrolysis. X-ray.

HYPOCHONDRIASIS.— (See Melancholia.)

HYSTERIA.— (See page 449.)

ICHTHYOSIS.— (See page 423.) X-ray.

INSOMNIA.— (See page 456.) Electric arc bath. Head breeze. Wave current. Auto-condensation couch.

IRITIS.— (See page 379.) Direct current.

JAUNDICE.— (See page 401.) Induced current. Incandescent light bath.

KELOID.—(See page 417.) Electrolysis. X-ray.

LARYNGITIS.—*Acute and Chronic.* (See page 375.) Concentrated arc light. Blue light.

Tubercular. (See page 375.) Cupric phoresis. X-ray.

LATERAL SCLEROSIS.—(See Locomotor ataxia.)

LENTIGO.—*Freckles.* (See page 423.) Electrolysis.

LEUCORRHEA.— (See Endometritis, cervical.)

LEUKEMIA.—(See page 407.) X-ray.

LEUKOPLAKIA.—(See page 374.) X-ray. Electro-cautery.

Locomotor ataxia.—(See page 433.) Direct current. Electric bath. Static wave current. Static sparks. Static induced current. Blue light. X-ray. Phoresis. Fraenkel exercises.

Lupus.—*Erythematosus.* (See page 423.) Concentrated arc light. X-ray.

Vulgaris. (See page 423.) Concentrated arc light. X-ray. Brush discharge. Vacuum tube discharge. Auto-condensation.

Mania.—(See page 449.) Static head breeze.

Malposition of the Uterus.—(See page 337.) Direct current. Induced current. Static wave current.

Melancholia.—(See page 448.) Direct current. Static insulation.

Menopause.—(See page 344.) Direct current. Induced current. Stimulation of thyroid gland by the direct current. Static insulation.

Menorrhagia.—(See page 341.) Direct current.

Menstruation.—*Scanty.* (See page 333.) Direct current. Induced current.

Metritis.—(See page 339.) Cupric-phoresis.

Senile. (See page 340.)

Milium.—(See page 425.) Electrolysis.

Molluscum Contagiosum.—(See page 425.) Electrolysis.

Morphea.—(See page 426.) Direct current.

Morvan's Disease.—(See Erythromelalgia.)

Myalgia.—(See page 463.) Incandescent light baths. Arc light baths. High frequency vacuum electrodes.

MYELITIS.— (See page 436.)

NAEVUS.—*Lipomatodes.* (See page 424.) Electro-cautery. Electrolysis.

Pigmentosus. (See Angioma.) (See page 425.) Electrolysis.

Pilosus. (See page 425.) Electrolysis.

NEOPLASMS OF THE NOSE.— *Benign.* (See page 373.) Electro-cautery snare.

Malignant. Zinc phoresis.

NEPHRITIS.— (See page 406.) Induced current. Static treatment. Incandescent bath. Vibratory stimulation.

NEURALGIA.— (See page 439.) Direct current. Induced current. High frequency vacuum tube. X-ray.

Tic douloureux. (See page 440.) Direct currents with large amperage.

NEURITIS BRACHIAL.— (See Bursitis subacromialis and Sciatica.) (See page 444.)

NEURASTHENIA.—(See page 451.) Static electricity. Direct current. Induced current. Static induced current. Auto-condensation. Electric bath. Electric light bath.

OPHTHALMIA NEONATORUM.— (See page 383.)

Cerebral. Direct current, longitudinal from forehead to nape of the neck.

OBESITY.— (See page 468.)

ORCHITIS.— (See page 353.) Direct current. Phoresis, with iodide of potassium.

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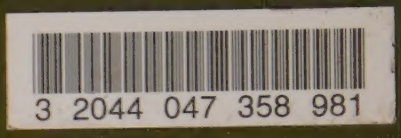
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